Weeds

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Journal of the Association of Regional Weed Control Conferences

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WEED SOCIETY OF AMERICA

The Weed Society of America was founded at Fargo, North Dakota on December 8, 1954. The formation of this Society grew out of the action of the Association of Regional Weed Control Conferences. The North Central, Northeastern, Southern and Western Weed Control Conferences, through resolutions, directed their delegates to the Association to develop the framework for organizing the Weed Society of America.

The delegates adopted a temporary constitution for the Society which is to be used until the time of the charter meeting of the Society in New York City in January 1956. It was further decided by the delegates that all persons joining the Society during the calendar year of 1955 would become charter members and that a permanent constitution would be considered at the 1956 meeting.

The object of the Society is to encourage and promote the development of knowledge concerning weeds and their control through publishing research findings, fostering high standards of education, encouraging effective regulation, and promoting unity in all phases of weed work. The Society is dedicated to cooperate closely with regional weed control conferences in these endeavors.

The membership of the Society is open to individuals and organizations of all nations interested in its objectives. Membership dues are $6.00 for 1955, which includes a subscription to the journal, WEEDS. The WEEDS journal which was initiated by the Association of Regional Weed Control Conferences is to be the official publication of the Society. Dr. K. P. Buchholtz, Department of Agronomy, University of Wisconsin, Madison, Wisconsin was named editor and Dr. W. C. Jacob, University of Illinois, Illinois Agricultural Experiment Station, Urbana, Illinois was named business manager of WEEDS.

All persons who are interested in becoming charter members of the Society should complete the attached membership application form and return it and their remittance, *payable to the Weed Society of America,* to Dr. W. C. Jacob. All members interested in publishing papers in WEEDS should send their manuscripts to Dr. K. P. Buchholtz, the new editor.

Dr. Minarik and Dr. Sweet, Editor and Business Manager respectively of Volume III of WEEDS have agreed to complete that Volume. Inquiries regarding Volume III should be directed to Dr. C. E. Minarik, "C" Division, Camp Detrick, Frederick, Maryland or to Dr. R. D. Sweet, Vegetable Crops Department, Cornell University, Ithaca, New York.

Future inquiries regarding publishing manuscripts in Volume IV of WEEDS should be directed to Dr. Buchholtz and inquiries regarding subscriptions, advertising, and other business affairs of WEEDS should be directed to Dr. W. C. Jacob.

The officers of and delegates to the Association of Regional Weed Control Conferences are to serve as the Executive Committee of the

Society until the election of officers by the Society at the business meeting in New York in 1956. Officers reappointed to serve during the organizational period were: R. H. Beatty, President; W. B. Ennis, Jr., Vice-president; and W. C. Shaw, Secretary-Treasurer. The first meeting of the Weed Society of America will be held on January 4, 5, 6, 1956 at the Hotel New Yorker, New York City, New York.

WEED SOCIETY OF AMERICA

Application For Membership

The membership of the Society shall be open to individuals and organizations of all nations interested in the objectives of the Society. Applications are being accepted for Active and Sustaining Memberships only, prior to the formal acceptance of the Constitution by the membership at the first meeting in January 1956. Persons joining the Society during the period January 1, 1955 to December 31, 1955 are Charter Members.

I. *Active Membership.* Active members are persons who are interested in weeds or their control and who have remitted their annual dues to the Treasurer. Active members may attend all Society meetings, vote on all matters pertaining to the Society, and may hold office. The active membership fee includes a subscription to one volume (1955) of WEEDS, $6.00..... ☐

II. *Sustaining Membership.* Sustaining members shall consist of persons or organizations who contribute 100 dollars or more annually for the permanent support of the Society. The names of such members shall be printed in all issues of the official publication of the Society and in the programs of regular meetings. The sustaining membership fee includes a subscription to one volume (1955) of WEEDS $100.00..... ☐

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Weeds

JOURNAL OF THE ASSOCIATION OF REGIONAL WEED CONTROL CONFERENCES.

VOLUME III OCTOBER 1954 NUMBER 4

Preplanting Applications of IPC and CIPC for Selective Control of Wild Oats. *(Avena fatua)*[1]

A. F. WIESE and R. S. DUNHAM[2]

IN recent years, chemical control methods have been discovered for most common annual weeds with the notable exception of wild oats. Isopropyl N-phenyl carbamate (IPC) and isopropyl N-(3–chlorophenyl)-carbamate (CIPC) appeared promising in 1950 when they successfully controlled wild oats in barley at University Farm, Saint Paul, Minnesota. In the spring of 1951, investigations were started in an attempt to evaluate these two chemicals further for selective use in field crops.

REVIEW OF LITERATURE

The action of carbamate on plants was first described in 1929 by Friesen (7), who used phenyl urethane (a phenylcarbamate) to show that a concentration of 0.002 per cent delayed and reduced germination of oats and wheat. The selective herbicidal properties of carbamates were demonstrated by Templeman and Sexton (11) in 1940, when they killed oats in wild charlock with ethyl phenyl carbamate. They later found that IPC could produce similar effects at much lower rates of application. Ennis (2) showed that IPC must be taken up from the soil to be most toxic to cereals.

Recently, the tolerance of many crops and weeds has been determined by several workers (1, 2, 5). In general, their results agree with Ennis (4) who found that the cereals, flax, and buckwheat were most adversely affected and that legumes and many vegetables were most resistant to injury when grown in soil treated with IPC.

IPC and related compounds are usually considered to be more

[1]Contribution from the Dept. of Agronomy and Plant Genetics, University of Minnesota, Saint Paul, Minnesota. Paper No. 3135 Scientific Journal Series, Minnesota Agricultural Experiment Station. Part of a thesis submitted to the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2]Formerly Graduate Assistant, University of Minnesota, now Assistant Agronomist, Texas Agricultural Experiment Station, and Professor of Agronomy, University of Minnesota, respectively. Acknowledgement is made to Columbia Southern Corporation for financial assistance in conducting these trials.

toxic to grasses than to broadleaved plants, but Ennis (2) points out that a range of selectivity exists for the broadleaved families of Solanaceae and Cucurbitaceae, and Mitchell and Marth (9) showed a similar relationship in grasses.

Freed (6) states that many factors influence the effectiveness of IPC as an herbicide; e.g., the species of grass, the period of residual activity which is largely affected by temperature and microbial activity, the stage of plant growth and the supply of soil moisture.

METHODS AND MATERIALS

Three experiments were designed to study the possibility of using IPC or CIPC selectively for the control of wild oats: (1) a laboratory study of the relative tolerance of wild oats and various crop species to these chemicals, (2) field trials to test the relative tolerance of these species, and (3) greenhouse studies of factors influencing the herbicidal action of the materials.

Laboratory Study of Species Tolerance

A preliminary petri-dish study was designed to determine the relative tolerance of different species to CIPC at the time of germination. Wild oats and ten crops were used. Seeds of Minhybrid 503 corn, Redwing flax, Mars barley, Blackhawk soybeans, Multiplier field peas, Andrew oats, common buckwheat, Proso millet, Lee wheat and sugar beets were placed on blotter paper in a germinator at room temperature and left until the radicles broke through the seed coat. Then five germinating seeds of each crop were placed on filter paper in a petri-dish. The filter paper was moistened with either 4 ml. of water which served as a check, or one of three solutions of CIPC. The concentrations of CIPC used were 0.6, 1.0, and 2.0 ppm. Each treatment was replicated four times. At the end of four days, the average radicle length of the treated seeds was compared to that of the seeds soaked in water. The data expressed as per cent of check were used for comparison between species.

Field Trials of Species Tolerance

It was apparent from the preliminary investigation that wide differences in tolerance to the herbicide existed among crop species at germination time. Three field trials were set up during 1951 and 1952 to determine whether the results from the petri-dish study applied to field conditions. Two of the field trials were carried on at University Farm, Saint Paul, Minnesota, on Waukegan silt loam soil, and another was laid out at the Northwest School and Station, Crookston, Minnesota, on Fargo silty clay loam soil. Wild oats had to be sown for the University Farm trials, but they occurred naturally in the soil at Crookston. In all of the trials, the herbicides were mixed into the soil prior to sowing crops. This was done by first applying the chemical to the soil with a plot sprayer described by Robinson and Dunham (10), followed immediately by disking the land three times with a tandem disk.

The first field experiment at University Farm was planned to determine if wild oats could be controlled selectively in those crops that proved most tolerant in the petri-dish study. In addition, sunflowers were included in the field trial. The experimental design was a duplicated randomized block of the following chemical treatments: 0, 2.5, 5.0, 10.0, and 15.0 pounds of CIPC per acre. Plots were 40 by 18 feet. Three rows each of Ottawa Mandarin soybeans, Advance sunflowers, Minhybrid 800 corn, Chang field peas, sugar beets, and wild oats were sown with a "Planet Jr." across each plot. When the crops were nearly mature, stand data were taken by counting the plants in 36 feet of row for corn and sugar beets, 15 feet of row for sunflowers and soybeans, and 5 feet of row for field peas and wild oats.

The second trial at University Farm was an attempt to control wild oats in small grains and flax. It was a split plot design with three replications. The main plots consisted of rates of herbicides on which oats, barley, wheat, and flax were sown in a randomized order. Subplots of emulsifiable IPC, emulsifiable CIPC, and a wettable powder of IPC were then randomized on each crop. Each chemical plot was 6 by 8 feet. The soil was spring plowed and well disked just before the three chemicals were applied on May 2, 1951, at 0, 5, 8, 10, and 15 pounds per acre. Wild oats were sown at 90 pounds per acre about 3 inches deep with a grain drill over the whole area on May 4. Andrew oats, Mars barley, Lee wheat, and Redwing flax were sown at 64, 96, 90 and 40 pounds per acre respectively. The crops and wild oats on the check plots emerged May 11, but the crops and wild oats on the treated plots were delayed about two days. None of the treatments gave satisfactory selective wild oats control; consequently, data were limited to square yard stand counts of wild oats and crops on the wheat and flax plots.

The experiment at Crookston was started on May 10, 1952, to determine if CIPC could control naturally occurring wild oats in soybeans and sugar beets on the heavy soils of the Red River Valley. The experimental design was a randomized block with three replications; the treatments were an untreated plot and 5, 10, and 20 pounds of CIPC per acre. Each plot was 21 by 18 feet. Three rows of Ottawa Mandarin soybeans and three rows of sugar beets were sown across each plot with a "Planet Jr.". On July 11, stand counts were taken from 5 feet of the center row of each crop. At the same time, notes were taken on the control of wild oats and grass weeds, *Setaria viridis, S. lutescens* and *Echinochloa crusgalli.*

Greenhouse Studies of Factors Affecting Herbicidal Action

It was observed from the field trials that higher rates of CIPC were required to control wild oats at Crookston than at University Farm. Several factors which could have affected the phytotoxicity of the phenyl carbamates applied to the soil were: the depth at which the chemicals were placed in relation to the seed, the soil type, and the wild oat type at a particular location. Two greenhouse trials

were conducted to investigate some of these factors under controlled conditions.

Since the trials at Crookston were made on wild oats occurring naturally throughout the plow sole and those at University Farm were made on wild oats sown at a single depth with a grain drill, the relation of seed depth and chemical placement was studied. The experimental design was a split plot with four replications. The main plots were chemical placements and the subplots were depths of seedings. A plot was considered to be one 5 inch pot in which twenty seeds of wild oats were planted. The chemical placements were: untreated soil in greenhouse pots, CIPC on top of the soil, CIPC mixed with the upper 0.5 inch of the soil, CIPC mixed with the top 1.5 inches of soil, and CIPC mixed throughout the depth of the soil. The CIPC was applied at a rate equivalent to one pound per acre for all treatments. The chemical was dissolved in 10 c.c. of water and mixed with the proper amount of soil. Downward leaching of the chemical was prevented by subsurface watering. The two depths of seed placement were 0.5 and 1.5 inches. After eighteen days of growth at 70° F., the number of wild oat plants, the green weight of the top growth, and the dry weight of the roots were recorded for each pot.

In the second greenhouse experiment, the effect of soil types and of ecotypes on the response of wild oats to CIPC was studied. The experimental design was a split plot with four replications. The main plots were rates of CIPC at 0, 0.25, and 1.0 pounds per acre; the subplots were soil types, Fargo silty clay loam from Crookston, Waukegan silt loam from University Farm, and Hubbard sandy loam from Saint Peter; and the sub-subplots were two wild oat ecotypes, one from a field near Crookston, and the other from the vicinity of Baudette. On the basis of the classification by Malzew (8), the Crookston ecotype appeared to be predominantly *Avena fatua*, variety intermedia, with a few seeds of subvariety pilibarbis. The Baudette oats were mostly variety villis mixed with variety intermedia. Each plot was one 5 inch pot of soil in which fifty seeds of wild oats were planted. The proper amount of chemical was applied with enough water to wet the soil in each pot to about field capacity. After twenty days of growth, the normal plants per pot were counted.

EXPERIMENTAL RESULTS

Laboratory Study of Species Tolerance

In the petri-dish study, the crops and wild oats fell into three response groups as shown in table 1. Buckwheat, wild oats, wheat, barley, oats, and flax were the most susceptible crops as indicated by reduced radicle length. The differences among these six crops were not statistically significant. Corn and millet were intermediate in their reactions of CIPC and were injured significantly less than flax, the most tolerant crop of the susceptible group. Field peas, sugar beets, and soybeans were significantly more tolerant to CIPC than corn or millet. Field peas were significantly injured, but sugar beets and soybeans were not.

Table 1. Length of radicle on crop seeds and wild oats four days after germination in petri dishes on blotters wet with CIPC. (Average of 0.6, 1.0 and 2.0 ppm. concentrations).

Crop	Radicle length as per cent of check
Untreated check	100.0
Buckwheat	7.9**
Wild oats	9.1**
Wheat	9.3**
Barley	12.6**
Oats	16.8**
Flax	20.7**
Corn	44.3**
Millet	45.3**
Field peas	79.2*
Sugar beets	88.7
Soybeans	92.1
L.S.D. 5%	16.4
L.S.D. 1%	22.1

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

Field Trials of Species Tolerance

In the first field trial at University Farm which tested the relative tolerance of sugar beets, soybeans, sunflowers, corn, field peas, and wild oats to preplanting applications of CIPC, the data indicate that wild oats could be selectively eliminated from all crops except corn (table 2). Wild oats were practically eliminated at 2.5 pounds of CIPC per acre, indicating that they are very susceptible to injury by the chemical. The stand of corn on the plots treated with 5 pounds per acre was greatly reduced, but sugar beets, soybeans, field peas and sunflowers were not damaged by the 15 pound applications.

The second experiment at University Farm was designed to determine if wild oats could be controlled selectively in wheat, barley,

Table 2. The effect of CIPC on the stand of several crops and wild oats sown immediately after application and mixing of the chemical into the soil. University Farm.

Pounds per acre	Number of plants in a					
	36 ft. row		15 ft. row		5 ft. row	
	Corn	S. beets	Sunflower	S. beans	Peas	W. oats
Untreated	66	21	44	39	52	61
2.5	62	28	37	33	48	3
5	38**	21	46	40	49	0
10	13**	21	49	42	55	0
15	10**	21	41	37	47	0
L.S.D. .01	27.8	—	—	—	—	—

**Significant at the 1 per cent level.

Table 3. The effect of CIPC and two formulations of IPC on the stand of flax, wheat, and wild oats sown immediately after the chemicals were applied and disked into the soil. University Farm.

Formulations	Pounds per acre	No. of plants per square yard		
		Flax	Wheat	Wild oats
CIPC	0	696	128	116
	5	161**	13**	46**
	8	109**	18**	20**
	10	85**	16**	21**
	15	35**	5**	7**
IPC	0	667	135	119
	5	228**	7**	19**
	8	114**	6**	7**
	10	72**	9**	14**
	15	33**	4**	13**
Powdered IPC	0	579	153	117
	5	196**	13**	24**
	8	143**	11**	16**
	10	125**	7**	14**
	15	37**	4**	9**
L.S.D. .05	–	109.6	17.8	29.8
.01	–	148.9	24.2	40.5

**Significant at the 1 per cent level.

oats, and flax with CIPC and two formulations of IPC. Because injury was extremely severe on all crops, stands were counted only on wheat, flax, and wild oats. All treatments greatly reduced the stands of wheat, flax, and wild oats (table 3). In the case of flax, 15 pounds of any of the three formulations reduced the stand significantly more than 5 pounds. This was also true for 15 and 5 pounds of CIPC on wild oats. In wheat, there was no differential injury due to rates of chemical. In the analysis of variance for each crop and for wild oats, the F values for formulations of herbicides were not significant, indicating that in this trial, CIPC, IPC, and powdered IPC had the same phytotoxicity.

In the field trial at Crookston, the stand of soybeans was significantly reduced only by 20 pounds of CIPC per acre, whereas both the 10 and 20 pound rates reduced the stand of sugar beets (table 4).

Table 4. The selective control of wild oats and grass weeds in sugar beets and soybeans planted immediately after application and mixing of CIPC into the soil. Crookston.

Pounds per acre	Number of plants per 5 ft. row		Weed stand rating†	
	Soybeans	Sugar beets	Wild oats	Grass weeds
Untreated	18.0	16.0	5.0	4.7
5	20.3	12.6	3.3*	3.3*
10	22.0	5.0**	1.0**	2.7*
20	13.7*	0.7**	0.3**	1.0**
L.S.D. .05	5.2	6.6	1.5	1.5
.01	7.9	9.9	2.2	2.3

†Weeds and wild oats rated:
0 = no weeds remaining
6 = heavy infestation
*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

Control of both wild oats and grass weeds was very good at 20 pounds of CIPC. Ten pounds of CIPC reduced the stand of wild oats more than that of the other grassy weeds, indicating a certain specificity of CIPC for wild oats.

Greenhouse Study of Factors Influencing Herbicidal Action

The first greenhouse trial was designed to determine the effect of seed and chemical placement on the phytotoxicity of CIPC. The analyses of variance for stand, top growth and root growth of wild oats show that chemical placement, seed depth, and the interaction of seed-depth x chemical-placement were sources of variation (table 5). The data from which the analyses were made indicate that non-

Table 5. Seed and chemical placement study. The variances from the analyses of variance for stand, top growth, and root growth of wild oats.

Variation due to	DF	Stand	Top growth	Root growth
Chemical placement	4	101.687**	4.747**	0.357
error a	12	3.837	0.144	0.144
Seed depths	1	156.025**	0.838*	0.855**
Depths X chemicals	4	29.212**	0.545*	0.287**
error b	15	6.175	0.116	0.057

*P less than .05.
**P less than .01.

dormant wild oat seeds would germinate and grow normally if they were not in contact with the CIPC. This is illustrated in Figure 1, which is a graph of the interaction of seed-depth x chemical-placement using the data from the analysis of the wild oat top growth. When the chemical was put on top of the soil, the growth of wild oats planted at both depths appeared to be somewhat stimulated. This increase, however, was not statistically significant. If the CIPC was put into the upper 0.5 inch of soil, the seeds planted 1.5 inches deep grew almost normally, while seedlings from seeds planted 0.5 inch deep were killed immediately after emergence. All of the seedlings from both depths of planting were killed when the chemical was placed in the upper 1.5 inches of soil. When the CIPC was dispersed throughout the entire pot, the material was sufficiently diluted so that the growth of wild oat seedlings was only somewhat retarded.

The second greenhouse trial was an attempt to determine the effect of soil types and of ecotypes on the response of wild oats to CIPC. The analysis of variance for the data indicates that the important sources of variation in the study were the rates of CIPC, the soil types, wild oat ecotypes and the interaction of soil-types x rates of CIPC (table 6). The significant variance for wild oat ecotypes is not important because it indicates only that the average amount of germination of the two ecotypes for the entire experiment was not the same. This difference in dormancy was expected, because the Baudette ecotype was harvested one year earlier than the Crookston ecotype. To determine if the ecotypes responded differently to CIPC,

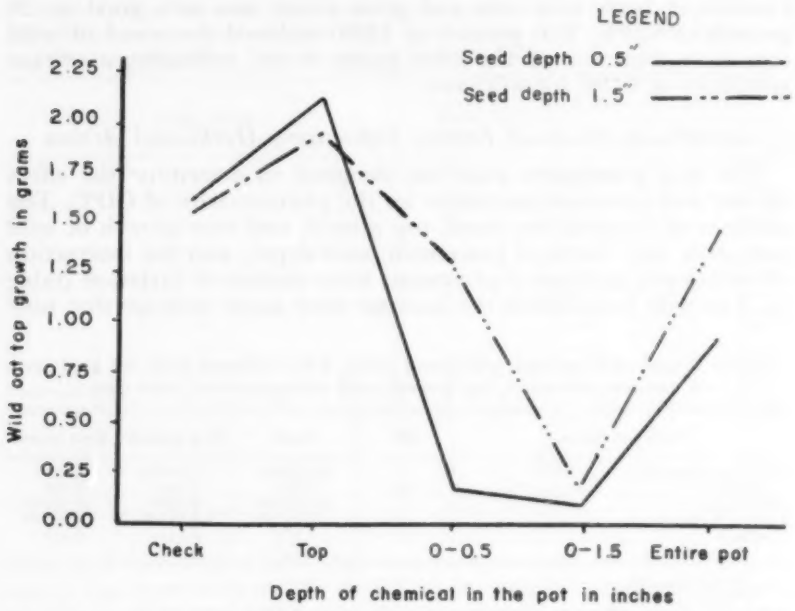

Figure 1. Interaction of depth x chemical-placement from the analysis of variance of wild oat top growth. Mean weight in grams of wild oats from seed placed at two depths in soil and treated with CIPC placed at different levels in the soil.

Table 6. The variances from the analysis of variance for normal seedlings per pot of two ecotypes of wild oats grown in three soil types treated with three rates of CIPC.

Variation due to	DF	Variance
Rates of CIPC	3	971.375**
error a	6	13.875
Soil types	2	396.125**
Soils × rates	4	218.500**
error b	18	16.560
Wild oat ecotypes	1	6,536.055**
Wild oats × rates	2	23.014
Wild oats × soils	2	31.764
error c	31	13.722

**P greater than .01.

it was necessary to ascertain whether the stand of one of the wild oat ecotypes was reduced more than that of the other by different chemical treatments. This was measured by the wild oats x rates-of-CIPC interaction, which was not significant.

The effect of soil type and rate of CIPC on the germination and growth of wild oats can be seen in Figure 2, which is a graph of the interaction of soil-types x rates-of-CIPC. The stands of wild oats on the check and plots receiving the 0.25 pound treatment were alike for all three soil types, but the number of plants on different soil

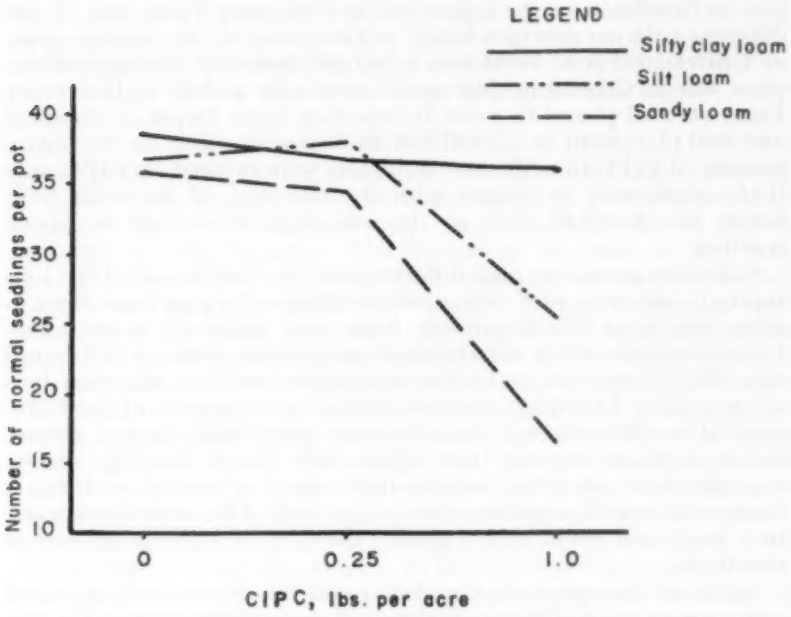

Figure 2. Interaction of soil-types x rates-of-CIPC from average of two seed lots grown on three soil types treated with three rates of CIPC.

types varied greatly when 1 pound of CIPC per acre was used. At this rate of application, the number of wild oat plants per plot was 37 on the silty clay loam soil, 25 on the silt loam soil and only 16 on the sandy loam soil. Apparently soil type influenced the amount of injury from CIPC.

SUMMARY AND DISCUSSION

The results of laboratory trials to determine relative tolerance of crop species and wild oats to CIPC in petri dishes were borne out in field experiments, indicating that tolerance in the field is actual tolerance of germinating seeds to CIPC. Selective control of wild oats sown with a drill in silt loam soil was possible with preplanting applications of CIPC and IPC as low as 2.5 pounds per acre in sugar beets, soybeans, field peas, and sunflowers, but it was impossible in corn, flax, wheat, barley, and oats because of injury to the crop. Where wild oat seeds occurred naturally throughout the plowed layer in Fargo silty clay loam, however, 10 pounds of the CIPC were required. This amount injured sugar beets, but not soybeans.

Higher rates of CIPC were required to control wild oats selectively at Crookston than at University Farm. Three possible explanations can be based on (1) the naturally infested soil at Crookston vs. the drilled-in wild oats at University Farm, (2) the heavier soil

type at Crookston vs. the lighter soil at University Farm, and (3) the different wild oat ecotypes found at Crookston vs. the ecotype sown at University Farm. Wild oats occurred naturally throughout the plow sole at Crookston, but those sown with a drill at University Farm were all placed in a one to two inch layer. Depth of chemical and seed placement in the soil had an important effect on the phytotoxicity of CIPC to wild oats. Wild oats were injured by CIPC only if the seeds were in contact with the chemical. If the seeds were below the chemical level in the soil, limited damage to plants resulted.

Soil types caused marked differences in the toxicity of CIPC. Less injury occurred to wild oats grown in Fargo silty clay loam than to those grown in Waukegan silt loam and Hubbard sandy loam. Injury was greatest on the Hubbard sandy loam. Weaver (12) found that IPC is adsorbed by cation exchangers and that adsorbed ions are nontoxic. This might explain variations in toxicity of the CIPC applied to different soil types because heavy soils have a greater cation exchange capacity than lighter soils. Water holding capacity may also have an effect because more water is needed to bring a heavy soil to field capacity than a light soil. The additional water in a heavy soil could give a greater dilution of a given amount of chemical.

Wild oat ecotypes from Crookston and Baudette which appeared to be composed of different varieties of *Avena fatua* responded similarly to CIPC applied to the soil, indicating that differences in the toxicity of the chemical between Crookston and University Farm were probably not caused by this factor.

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Some Factors Affecting the Tolerance of Peas to MCP and Other Growth Regulating Herbicides[1]

K. P. Buchholtz[2]

Peas grown for canning purposes are subject to infestations of weeds even though recommended cropping practices are followed. If weeds are numerous they cause reduced yields of shelled peas and variable maturity. The quality of the pack of peas may also be affected for floral buds and fragments of the weeds are difficult to separate from the shelled peas. Excessive costs for seed peas may result from using high seeding rates in an attempt to control weeds by increasing the competitive ability of the peas.

Preparations of dinitro materials and calcium cyanamid have been considered for control of broad-leaved weeds in peas. Neither material has attained widespread use, possibly due to variable control of weeds and crop injury. These materials also present a number of handling problems connected with their application. Herbicides of the growth regulating type, in general, have given more dependable results in the control of broad-leaved weeds. These herbicides have usually been considered too toxic to be considered for weed control in leguminous crops. However, peas possess sufficient tolerance to some of the herbicides of this group so that their use has been suggested for weed control in pea fields. Aberg, Hagsand, and Vaartnou (1) were among the first to mention the use of MCP (2–methyl, 4–chlorophenoxyacetic acid) for weed control in this crop. Andersen and L'Arrivee (2), Brit (3), Buchholtz (7), Hylmo (10), and Miller (12) have attempted to evaluate the use of MCP on peas. Many trials have been promising, but erratic results have prevented widescale recommendations for the use of MCP in canning peas. The present study attempts to evaluate some of the factors responsible for the variability noted.

Methods and Materials

Studies on the responses of canning peas to MCP and related materials were undertaken at the Wisconsin Agricultural Experiment Station during the period 1949–1954, inclusive. Methods used varied somewhat from year to year but, in the main, were similar. The pea seed was sown with a drill having a 6 inch spacing at the rate of approximately 240 pounds per acre. The Alaska variety of peas was sown most frequently but the varieties Pride, Shoshone, Bonneville, H–539 and Perfection were used in some seasons to extend the harvest season. After emergence of the peas, plots 12 feet

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[2]Assoc. Prof. Agronomy, University of Wisconsin, Madison, Wisconsin.

long and 5 rows wide were outlined in the planted areas with a hand cultivator. Only plots with a uniform stand of peas were used. An attempt was made to use cultural practices comparable to those in commercial production fields.

Application of herbicides in 1949, 1950, and 1951 was made with a hand spray gun described by Buchholtz (6). In 1952, 1953 and 1954 the plots were sprayed with a bicycle sprayer equipped with a flowmeter. Spray volumes used were 20 or 40 gallons per acre and were constant throughout a particular year unless designated otherwise. The spray was applied at a pressure of approximately 40 pounds per square inch. All application rates were based on the acid equivalent of the herbicide used. Four replications with a randomized complete block design were used in all studies. In 1953 and 1954 the area planted to peas was sown to a thin stand of turnips or mustard greens to simulate a weedy growth. In some trials it appeared as though the turnips or mustard had reduced the yield of shelled peas slightly. In the preceding years, the plots had a scattered stand of annual weeds which appeared to have no appreciable effect on the yield of the peas.

The plots were harvested when the peas on the untreated check plots had reached the canning stage. The three center rows of each plot were pulled. The pods were picked and then were shelled with the aid of a laboratory huller. Shelled pea weights were secured. Tenderometer readings of the shelled peas were recorded to indicate maturity.

The maturity of the peas was affected by many of the treatments. Delay in maturity often accentuated the reductions in yield. If the peas from various plots in a trial had been harvested at a comparable stage of maturity, it is likely that yield differences would have been less marked or not significant. Methods have been suggested by other workers for correcting the yields of peas to comparable maturities. In the present studies corrections were not made for there is no assurance at present that the correction factors used heretofore apply to peas delayed in maturity due to treatment with herbicides. Therefore, both yield data and tenderometer readings of the shelled peas must be considered when evaluating the data.

Factors studied during the investigation included the response of peas to various chlorinated phenoxyacetic acids, the sensitivity of peas to several preparations of MCP, the influence of rate of MCP application on pea injury, sensitivity of peas to application of MCP at several stages of growth, responses of several varieties of peas to applications of MCP and the influence of spray volume on toxicity of MCP.

RESULTS AND DISCUSSION

Toxicity of several phenoxyacetic acids

MCP is but one of the phenoxyacetic acids that have been considered for use as an herbicide. 2,4–D (2,4–dichlorophenoxyacetic acid) has been used widely for control of broad-leaved weeds in cereal crops. 2,4,5–T (2,4,5–trichlorophenoxyacetic acid) has been

shown to have particular value for use in the control of brush. Other members of the group such as DPA (3,4–dichlorophenoxyacetic acid) and CPA (4–dichlorophenoxyacetic acid) are also of interest for they are known to possess considerable physiological activity. Trials comparing the responses of peas to two or more of these herbicides were made in 1949, 1950, 1951, 1953 and 1954. In all cases, the amine preparations of the herbicides were used and applications were made when the peas were from 6 to 12 inches tall. The data obtained are summarized in Table 1.

Table 1. Shelled pea yields and tenderometer readings obtained from plots treated with several herbicides.

Herbicide	Appl. lb/A	Year of trial									
		1949		1950		1951		1953		1954	
		Yield lb/A	Tend. read.	Yield lb/A	Tend. read.	Yield lb/A	Tend. read.	Yield lb/A	Tend. read.	Yield lb/A	Tend. read.
MCP	0.125	—	—	2929	74	4129	124	2779	116	—	—
	0.25	3639	122	1946**	74	3719	110**	2819	117	3865**	133
	0.5	—	—	1435**	73	2993**	90**	2170**	107*	3515*	125
2,4-D	0.125	—	—	1762**	76	4194	126	—	—	—	—
	0.25	4055	126	1277**	75	3381**	114**	—	—	—	—
	0.5	—	—	399**	72	1913**	82**	—	—	—	—
2,4,5-T	0.125	—	—	—	—	—	—	2915	117	—	—
	0.25	—	—	—	—	—	—	2885	118	3710*	133
	0.5	—	—	—	—	—	—	2175**	104**	2459	107**
CPA	0.125	—	—	—	—	—	—	2829	121	—	—
	0.25	—	—	—	—	—	—	3039	113	3247	142*
	0.5	—	—	—	—	—	—	3107	123	3720*	146**
DPA	0.125	—	—	—	—	—	—	2294**	117	—	—
	0.25	—	—	—	—	—	—	2949	117	3815**	129
	0.5	—	—	—	—	—	—	3163	120	4418**	138
Check	—	3819	125	2687	74	4192	131	3083	119	2798	131
LSD 5% level		1009	9	356	NS	797	10	552	11	712	11
LSD 1% level		1383	12	482	—	1061	13	735	15	954	15

*Sig. different from check at 5 pct.
**Sig. different from check at 1 pct.

Results in the trial conducted in 1949 indicated that 2,4–D and MCP were of comparable toxicity to peas when applied at 0.25 lb/A. More extensive studies in 1950 and 1951 clearly showed that 2,4–D was usually the more toxic of the two herbicides. The difference in toxicity was especially apparent when the rate of application was increased to 0.5 lb/A. Results obtained by Birt (3), Buchholtz (4), Nielsen (13), Patterson (14) and Sexsmith (15) all indicate that MCP is generally less toxic to peas than 2,4–D when equivalent applications are made.

The data obtained in 1953 and 1954 indicate that CPA and DPA warrant further consideration as herbicides for use in peas. The yields of shelled peas obtained from plots treated with these materials are fully comparable to those obtained from plots on which MCP was used. Both CPA and DPA appear to be less toxic than MCP at the 0.5 pound per acre application rate. In both 1953 and 1954 the highest yields of peas were obtained with the higher rates

of CPA and DPA application. This appears to be due to the more complete control of weeds obtained with these applications without a corresponding increase in toxicity to the peas.

Comparison of MCP Preparations

Initial trials with MCP on peas included applications using the sodium salt, amine and ester preparations of this herbicide. Applications were made when the peas were from 6 to 12 inches tall. The data presented in Table 2 show that the ester preparation was

Table 2. Influence of MCP preparation on the yields of shelled peas and their tenderometer readings.

Preparation	Appl. lb/A	Year of trial					
		1949		1951		1953	
		Yield lb/A	Tend. read.	Yield lb/A	Tend. read.	Yield lb/A	Tend. read.
Na-salt	0.125	——	——	4211	132	2770	121
	0.25	3315	123	3998	110**	2914	119
	0.5	——	——	2617**	90**	2663	114
Amine	0.125	——	——	4129	124	2779	116
	0.25	3639	122	3719	110**	2819	117
	0.5	——	——	2993**	90**	2170**	107*
Ester	0.125	——	——	2809**	88**	——	——
	0.25	2154**	87**	2788**	79**	——	——
	0.5	——	——	1684**	76**	——	——
Check	——	3819	125	4192	131	3163	119
LSD 5% level		1009	9	797	10	552	11
LSD 1% level		1383	12	1061	13	735	15

*Sig. different from check at 5 pct.
**Sig. different from check at 1 pct.

distinctly more toxic to the peas than the amine and sodium salt preparations. There were no consistent differences between the yields of peas from plots sprayed with the sodium salt and amine preparations. The present data confirm that presented previously. Buchholtz (4) and L'Arrivee and Anderson (11) have reported that the butyl ester of MCP was more toxic than amine or sodium salt preparations. Birt (3) also has noted that ester preparations of MCP were more toxic than the sodium salt preparations.

A related problem is the possibility of variable results due to the use of MCP preparations compounded from materials varying in purity of 2–methyl, 4–chlorophenoxyacetic acid. Technical material has been reported to vary from 60 to 100 percent pure acid. The remaining materials have been assumed to be largely 2–methyl, 6–chlorophenoxyacetic acid, an isomer believed to have little or no plant growth regulating properties. Amine preparations of MCP derived from technical material having acid contents of 60 and 85 percent or 60, 85 and 100 percent purity were studied in trials made in 1951 and 1953. In the 1951 study the peas were about 12 inches tall at the time of application while in 1953 they were about 6 inches tall. Results obtained are shown in Table 3.

Table 3. Yields of shelled peas and tenderometer readings from plots treated with MCP derived from material varying in acid purity.

Acid purity	Appl. lb/A	Year of trial			
		1951		1953	
		Yield lb/A	Tend. read.	Yield lb/A	Tend. read.
60	0.125	3924	122	1936	117
	0.25	3738	110**	1600	118
	0.5	2922**	86**	583**	75**
85	0.125	4333	126	2009	118
	0.25	3701	111**	1636	114
	0.5	3064**	94**	657**	77**
100	0.125	——	——	1945	118
	0.25	——	——	1548	117
	0.5	——	——	1000**	90**
Check	——	4192	131	1739	116
LSD 5% level		797	10	415	8
LSD 1% level		1061	13	560	11

**Sig. different from check at 1 pct.

The data fail to show significant differences in the yield of peas from plots treated with the preparations derived from acids of varying degrees of purity. There was a tendency for the peas to show the least injury on plots treated with preparations having the highest degree of purity but the differences were not significant. The evidence favors the view that the use of preparations varying in MCP isomer content can be expected to give equivalent results.

Rate of Application

Peas have only a limited tolerance to MCP. Consequently, it is of importance to determine the maximum rates that can be used without appreciable crop injury. When the peas are growing in weedy fields, the application rate at which injury first becomes apparent can be expected to be greater than when treatments are made to weed-free plantings. If a particular application rate seldom gives injury to peas in a weed-free planting, it might be considered a promising one for use under field conditions.

The data shown in Table 4 are from trials in which the amine preparations of MCP were applied. Applications were made in all cases to peas approximately 6–12 inches tall. The data show that yields were usually not reduced significantly by applications of 0.25 pounds of MCP per acre. In 1950 the reductions in yield may have been unusually severe due to the use of the Alaska variety of peas and because applications were made at the 12 inch stage of growth. The possible influence of these factors will be discussed later. The range of tolerance was never great and yields were reduced in 6 out of 10 trials by the 0.5 pound per acre application. A noticeable delay in maturity is apparent following the 0.5 pound application. The yields of shelled peas are likely to be reduced substantially if harvest is made at the time the untreated portions of the field are at the canning stage. If harvest can be delayed until the treated portions

Table 4. Effect of MCP application rate on yields of shelled peas and their tenderometer readings.

Year of trial	Observation	Application rate—lb/A				LSD	
		0.125	0.25	0.5	Check	5 pct.	1 pct.
1950	Yield—lb/A	2929	1946**	1435**	2687	356	482
	Tend. read.	74	74	73	74	NS	——
1951	Yield—lb/A	4129	3719	2998**	4192	797	1061
	Tend. read.	124	111**	90**	131	10	13
1952	Yield—lb/A	3568	3848	4196	3807	NS	——
	Tend. read.	153	163	152	155	NS	——
1952	Yield—lb/A	2976	3032	2736	2656	NS	——
	Tend. read.	128	126	127	127	NS	——
1953	Yield—lb/A	2902	2821	2410**	3059	400	541
	Tend. read.	171	151*	102**	168	13	18
1953	Yield—lb/A	2763	2886	2579	2866	NS	——
	Tend. read.	125	120	114	118	NS	——
1953	Yield—lb/A	1956*	1593	940**	1592	274	367
	Tend. read.	129	126	88**	128	11	15
1953	Yield—lb/A	2779	2819	2170**	3083	552	735
	Tend. read.	116	117	107*	119	11	15
1953	Yield—lb/A	1963	1597	747**	1739	240	324
	Tend. read.	117	116	81**	116	5	7
1954	Yield—lb/A	——	3865**	3515*	2798	712	954
	Tend. Read.	——	133	125	131	11	15

*Sig. different from check at 5 pct.
**Sig. different from check at 1 pct.

of the field are at the optimum canning stage, the reduction in the yield will be materially less or it may not occur. The 0.25 pound application is sufficient to control a number of annual broad-leaved weeds in the early vegetative stage. The use of from 0.25 to 0.5 pounds of MCP per acre is necessary to control the floral bud development of more tolerant perennial weeds such as Canada Thistle.

Date of application

Soon after studies were initiated, it appeared as though the stage of development of the pea plant at time of treatment influenced the yield of shelled peas. Pea plants usually recovered more rapidly from MCP applications made in the earlier stages of development. With these earlier treatments the maturity of the peas was not retarded as greatly and yields were more comparable with those from the check plots. The amine preparation of MCP was used in all studies of this factor. The data obtained in 1952, 1953 and 1954 are shown in Table 5.

The results were not consistent. In 1952 treatment with 0.25 pounds per acre of MCP at three stages prior to bud failed to reduce the yields of shelled peas significantly. In 1953, however, the treatment at the 10 inch stage reduced yields substantially but was much less injurious when made earlier. In 1954 the reverse occurred. In one trial much more severe reductions in yield were obtained when applications were made to peas about 6 inches tall than when they

Table 5. Yields of shelled peas from plots treated when the peas were at several stages of development.

Stage of development	Appl. lb/A	Year of trial							
		1952		1953		1954		1954	
		Yield lb/A	Tend. read.	Yield lb/A	Tend. read.	Yield lb/A	Tend. read.	Yield lb/A	Tend. read.
2 inch.....	0.125	3156	149	2995	157	——	——	——	——
	0.25	3183	146	3133	147**	——	——	——	——
	0.5	2710**	140	3075	144**	——	——	——	——
6 inch.....	0.125	3568	153	2902	171	2019**	96**	2289	92
	0.25	3848	163	2821	151**	1538**	86**	2114	89
	0.5	4196	152	2410**	102**	864**	83**	1837	83**
10 inch.....	0.125	3558	147	1508**	171	3570	161	2531	90
	0.25	3672	159	810**	151**	2609**	165*	2530	89
	0.5	3163	121**	358**	84**	1164**	141**	2215	83**
Check.....	——	3807	155	3059	168	3708	158	2497	92
LSD 5% level		689	17	400	13	428	6	NS	5
LSD 1% level		933	23	541	18	583	9	——	7

*Sig. different from check at 5 pct.
**Sig. different from check at 1 pct.

were 10 inches tall. In a second trial the differences were less marked but the trend was the same. It is reasonable to assume that in cases where the maturity is delayed that earlier treatments will result in smaller yield reductions because of the greater length of time available for the recovery of the treated plants. Hagsand (8) found in his work that peas show greater yield reductions when treated at the later stages of development. It is possible that the higher temperatures which usually prevail as the season progresses increase the sensitivity of peas to herbicides. If this occurs considerable variability in response of the peas might be expected for climatic conditions vary from year to year. Until a more exact knowledge of the effect of weather is available it is probable that treatment at the 6 inch stage of growth is most practical.

Varietal Variations

An additional source of variation is the variety of peas used in the trial. It is well known that varieties of corn, oats, flax and a number of other crops vary in their tolerance to herbicides. To study this factor peas of the Alaska, H–539 (Perfected Wales type), and Perfection varieties were planted in adjacent blocks on the same date. Applications of MCP as the amine preparation were made on June 4 and again on June 10 in a uniform manner, using rates of 0.125, 0.25 and 0.5 lb/A. On June 4 the peas were approximately 6 inches tall. On June 10 the peas were about 10 inches tall with the Alaska variety being somewhat taller than the other two varieties. When the peas of each variety were at the canning stage they were harvested. Results are shown in Table 6.

The Alaska variety was much more susceptible to the effects of MCP in this trial than either the H–539 or the Perfection varieties. This response was consistent for both dates of application and for

Table 6. Yields of shelled peas obtained from three pea varieties following application of MCP.

Variety	Growth stage at treatment	Appl. lb/A	Yield lb/A	Ave. yield pct. check	Tenderometer reading
Alaska	6 in.	0.125	2019**	52.9	96**
		0.25	1538**		86**
		0.5	864**		83**
	10 in.	0.125	3570		161
		0.25	2609**		165*
		0.5	1164**		141**
	Check	——	3708		158
	LSD 5% level		428		6
	LSD 1% level		583		9
H-539	6 in.	0.125	2289	90.2	92
		0.25	2114		89
		0.5	1837		83**
	10 in.	0.125	2531		90
		0.25	2530		89
		0.5	2215		83**
	Check	——	2497		92
	LSD 5% level		NS		5
	LSD 1% level		——		7
Perfection	6 in.	0.125	2843	102.5	117
		0.25	2446		111
		0.5	2689		114
	10 in.	0.125	1760*		120
		0.25	3840**		128*
		0.5	2819		111
	Check	——	2667		119
	LSD 5% level		841		9
	LSD 1% level		1153		12

*Sig. different from check at 5 pct.
**Sig. different from check at 1 pct.

the various rates of application. No explanation is available for the inconsistent yields of peas from the Perfection variety which was treated at the 10 inch stage. The substantial differences in response to MCP applications would indicate that the sensitivities of pea varieties should be studied before recommendations are given for the use of this herbicide on peas.

Spray Volume

The fact that the ester preparation of MCP was distinctly more toxic than the amine or sodium salt preparations suggested that a major portion of the tolerance of peas to MCP is due to surface characteristics of the pea leaf. The leaves of peas have an unusually waxy surface to which spray droplets do not adhere easily. Herbicides contained in spray droplets that do adhere to such leaf surfaces may not be absorbed as fast as from spray droplets with better wetting characteristics. This response will be influenced by the spray volume used for the more concentrated sprays have a lower surface tension and the droplets wet and spread more easily on the leaf surface.

The application of the more concentrated, low volume sprays is usually accomplished by using nozzles with smaller orifices. When

the nozzles with the smaller orifices are operated at uniform pressures the result is a spray with smaller droplets. Hylmo (10) considered this problem and presented data to show that the leaf area covered with spray droplets will be considerably greater when the droplets have smaller diameters. If it is assumed that absorption through the cuticle is proportional to the area covered with the spray droplets and to the concentration of the spray used, it is possible that increased plant injury may follow the use of low volume applications. Such increase in injury will be most apparent when treating plants where the major factor affecting tolerance is limited absorption of the herbicide through the leaf epidermal tissues rather than tolerance of the herbicide by the cellular constituents of the plant.

Studies of this factor were made in both 1953 and 1954. Peas 6 inches in height were treated with an amine preparation of MCP at rates of 0.125, 0.25, and 0.5 pounds per acre using spray volumes of 40, 20, 10, and 5 gallons per acre to apply each rate of MCP. Spraying Systems Co. nozzles with orifice tips numbered 8004, 8002, 8001, and 800067 were used to make the applications with an operating pressure of 40 pounds per square inch. The Alaska variety of peas was used in both years. The results obtained are shown in Table 7.

Table 7. Shelled pea yield and tenderometer readings following treatment with MCP in several spray volumes in 1953 and 1954.

Spray volume gal/A	Appl. lb/A	1953		1954	
		Yield lb/A	Tend. read.	Yield lb/A	Tend. read.
Check	——	1592	128	3061	157
40	0.125	1956*	129	2006**	161
	0.25	1593	126	833**	——
	0.5	940**	88**	263**	——
20	0.125	1986**	127	1436**	159
	0.25	1160**	106**	493**	——
	0.5	704**	77**	80**	——
10	0.125	1717	127	1478**	162
	0.25	778**	80**	493**	——
	0.5	669**	78**	100**	——
5	0.125	921**	90**	1136**	163
	0.25	616**	74**	151**	——
	0.5	467**	70**	32**	——
LSD 5% level		274	11	Transformed	——
LSD 1% level		368	15	——	——

*Sig. different from check at 5 pct.
**Sig. different from check at 1 pct.

The data show clearly that greater injury resulted when the more concentrated, low volume sprays were applied even though equivalent applications per acre of MCP were made. In 1953 reducing the spray volume from 40 to 5 gallons per acre gave approximately the same reduction in yield as increasing the application rate from 0.125 to 0.5 pounds per acre at the 40 gallon per acre spray volume.

In 1954 the peas were injured severely by all treatments and quantities of shelled peas harvested were insufficient in many instances to secure a tenderometer reading. The trends obtained are consistent with results secured in 1953 for the lower spray volumes were more injurious to the peas than the higher ones. The data presented by Hellquist (9) and more recently by Sexsmith (15) substantiate the results obtained. Buchholtz (5) reported in a previous study that no differences in toxicity to peas were obtained from applications of 2,4–D applied in 80, 40 and 20 gallons of spray per acre. The present data show that at times the use of 40 gallons results in a decrease in toxicity over 20 gallons per acre.

SUMMARY

1. MCP is materially less toxic to canning peas than 2,4–D. 3,4–dichlorophenoxyacetic acid and 4–chlorophenoxyacetic acid appear to be no more toxic to peas than MCP while 2,4,5–T is probably slightly more toxic. The effectiveness of the two former materials in controlling weeds is not fully known but they were effective on mustard in these studies.
2. Ester preparations of MCP were significantly more toxic to peas than the amine and the sodium salt preparations. The two latter preparations did not differ in their toxicity to peas in this study.
3. No significant differences in toxicity to peas were found due to the use of MCP preparations derived from technical material varying in the purity of the 2–methyl, 4–chlorophenoxyacetic acid.
4. Peas have only limited tolerance to MCP. Applications of 0.25 pounds per acre of MCP to peas 6 inches tall occasionally resulted in yield reductions in this study. Application of 0.5 pounds per acre frequently resulted in considerable reductions in yield.
5. Peas are probably the most sensitive to applications of MCP in the more advanced stages of development but climatic or other factors cause considerable variation in the stage of greatest sensitivity.
6. In one trial peas of the Alaska variety were shown to be considerably more sensitive to applications of MCP than those of the varieties H–539 and Perfection.
7. Use of low gallonage sprays increased the injury to the peas materially. Use of less than 40, or perhaps 20, gallons of spray per acre is likely to result in increased injury to the peas.
8. MCP is a promising herbicide for use in canning peas because of its known toxicity to broad leaved weeds found in pea fields and because of its limited toxicity to peas when applied under favorable conditions.

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Teaching Aids in Weed Plant and Seed Identification

LLOYD R. WILSON, *Extension Weed Specialist, South Dakota State College, Brookings, South Dakota*

THE basis for a sound weed control program is the ability of the majority of the people to identify weed plants and seeds. Too often a patch of weeds becomes a menace to the community before the seriousness of it is realized. Lack of interest in identification led to the investigation of methods, aids and techniques that could be employed to reach and teach people, both adults and youth, to identify weed plants and seeds. The approach was through weed plant identification mounts, weed seed identification boards and through the use of slides. Also utilized were tours, field trips, botany schools, etc. Emphasis will be placed on aids that have been constructed for general use for indoor meetings. It should be stressed at the outset that there is no best way, one needs to utilize every method at his command.

WEED PLANT IDENTIFICATION MOUNTS

To meet the need of weed plant identification, sets of twenty weed plant mounts were developed. These included the 8 primary noxious, 8 secondary noxious and 4 common weeds that cause farmers' losses. The mounts are numbered from 1 to 20. These are laid out on tables with spacing between mounts depending on the number of people participating. This is nothing new. It is the approach to obtain participation that is different. Multiple choice forms were developed. These are numbered the same as the mounts. After each number are 3 to 5 names of weeds one of which is the correct name. The one which is believed to be correct is underlined by the participant.

Why are multiple choice answers used? Using multiple choice we found that participation was nearly 100% whereas when participants were required to identify and write the name of the weed very few would take part.

The following results have been observed:

1. Participants observe the plant, study the names and select the one which is correct.
2. Participants correct their own paper. The identification characteristics are pointed out. Often time we use slides to further point out characteristics.
3. They very often go back and carefully study those which were wrong.
4. It tests their knowledge of weed identification and many become interested. Many patches of weeds have been found through the above process.
5. Both 4-H members and adults enjoy identification work.

WEED SEED IDENTIFICATION BOARDS

As in the case of the weed plants an effort was made to make the seed identification project self teaching. The boards (Fig. 1) are constructed of $\frac{3}{8}$ inch tempered masonite 16 x 21 inches. The seed wells

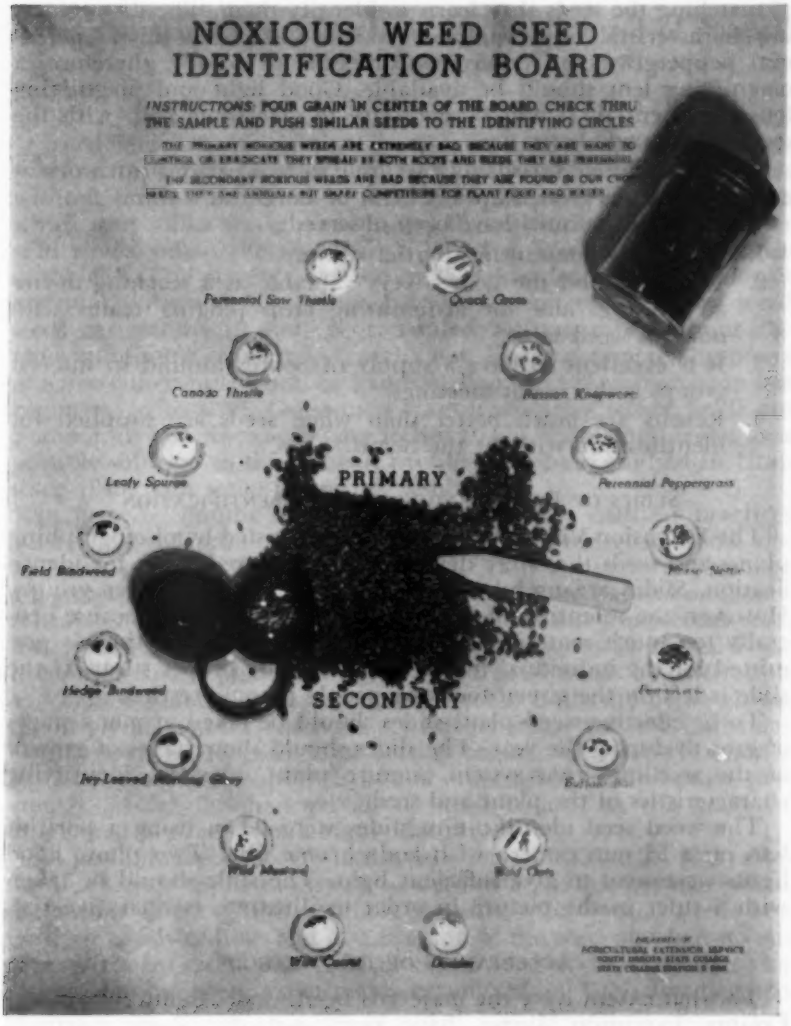

Figure 1. Noxious weed seed identification board.

are ¾ inch in diameter arranged in a diamond shape with our 8 primary noxious weeds at upper and 8 secondary noxious weeds at the lower portion of the board. The backs of the seed well are covered with white tagboard and caps are of .001 plastic cut by a die. M31 plastic cement available from Minnesota Mining and Mfg. Co. was the only material that would hold the plastic caps. White or clear cement was desired but not available. The printing was done by silk screening. Milo Potas, Extension Visual Aids Specialist prepared the boards. A jar (2 x 3¼ inches) half filled with grain plus a supply of the 16 weed seeds is emptied onto the board and through a process

of matching the seeds they learn to identify them. The distinguishing characteristics of perennial sow thistle and canada thistle, perennial peppergrass and pennycress are difficult to see; therefore, a magnifying lens should be available. Good light and magnifying lens are essential. It will be necessary to give some help with the seeds mentioned above.

There are twelve boards to a set (one to two persons can work at each board) thus groups up to 24 can be taught at a time.

The following results have been observed:

1. Very good interest and participation.
2. 4-H clubs find the boards very valuable as a teaching device at meetings and for acquainting crop judging teams with noxious weed seeds.
3. It is excellent to have a supply of boards around to interest groups gathering at meetings.
4. Results are much better than when seeds are supplied for identification without the board.

SLIDES OF PLANTS AND SEEDS FOR IDENTIFICATION

The Extension Visual Aids Department assisted by photographing plants and seeds that were developed into colored slides for identification. Slides are useful to teach identification to larger groups. However, the retention of information is not as great because generally too much material is presented and insufficient time is permitted for the individual to give any one slide proper study. If the slide is left on the screen too long people become restless.

To be effective weed plant slides should be taken at many stages of growth during the year. The slides should show stages of growth of the seedling, root system, mature plant, blossom, identifying characteristics of the plant and seed.

The weed seed identification slides were taken using a portrait lens on a 35 mm camera with kodachrome film. Two photo flood lights were used to give sufficient light. The slide should be taken with a ruler in the picture in order to illustrate comparative size.

ACCEPTANCES OF THE METHODS

To what extent have the materials been used? About 20% of the County Extension Agents have purchased the above discussed materials.

About 50% of the County Extension Agents who did not purchase equipment borrowed from our supply. Many more will use them this year.

The County Extension Agents have felt that the materials have been very good teaching aids for work with 4-H members and adults in identification.

The materials discussed are only old tools given perhaps a new use. In extension education one works with people of many interests and problems; it is up to the extension specialist to search out the proper tools and techniques to satisfy those interests so that those concerned will proceed to solve their problems.

Promising Herbicidal Methods for the Control of Annual Weeds in Seed Crops of Onions*

L. R. Hawthorn, F. L. Timmons, and W. O. Lee**

A seed field of bolting onions is extremely difficult, if not impossible, to weed satisfactorily by hoeing or any mechanical means without serious reduction in seed yield, because of the ease with which seed stalks are broken. Injury to seed stalks results in lower seed yields, but if the weeds are allowed to grow they also reduce seed yields. The presence of weed seeds makes cleaning more difficult and may reduce yields further, because foreign material and weed seeds can rarely, if ever, be separated satisfactorily without the removal of some crop seed. Actually few, if any, commercial growers practice either cultivation or handweeding after the onion crop has begun to go to seed. Consequently, exceptionally weedy fields are common in onion-seed-growing sections. The use of herbicides as a possible solution to this difficult problem has been studied in Utah since 1949, with some promising results.

In growing onions for seed, several different cultural practices affect the weed problem. In the standard bulb-to-seed method, the bulbs are grown in the first year in practically the same way as they are grown for market. Weeds are controlled by mechanical or chemical methods or both. When the bulbs are set out the second year, the spacing between the rows may range from 30 to 36 inches. Prior to bolting, such a planting may be kept free of weeds by cultivation and handweeding more easily than when the bulbs are being grown the first year, because the rows are farther apart and the bulbs are farther apart in the row. After bolting begins, weed control rapidly becomes exceedingly difficult, if not impossible, as indicated previously. More efficient methods of weed control at this stage of onion seed production are highly desirable.

A preliminary report* indicated that 2,4–D acid (wettable-powder form), applied at a rate as high as 3 pounds per acre when the onions were beginning to bolt, would control annual weeds better than handweeding (and at a fraction of the cost) and had no adverse effect on either the yield of onion seed or its viability. The object of subsequent experiments conducted in Utah has been to explore more thoroughly the practical applications of the earlier findings as well as to test a few new herbicides that have indicated their possible usefulness in solving the problem of weeds in seed onions.

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*A progress report on cooperative experiments between the Agricultural Research Service, United States Department of Agriculture, and Utah Agricultural Experiment Station.

**Horticulturist, Horticultural Crops Research Branch; Senior Agronomist; and Assistant Agronomist, respectively, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

*Timmons, F. L., Hawthorn, L. R., and Webber, R. D. Possibilities of controlling annual weeds in seed onions by chemical methods indicated by experiments. Farm and Home Science (Ut. Agr. Exp. Sta.) 12 (2): 1, 2, 38, 39. 1951.

MATERIALS AND METHODS

The investigations followed two or three fairly well defined procedures each year. From the start, the chief interest was in tests of herbicides applied at the time the onions were beginning to bolt (usually in late May or early June). In all experiments the onion bulbs were planted early in April, in rows spaced 30 inches apart, with the bulbs 6 inches apart in the row. The onions were cultivated and handweeded according to normal practice each year until the onion seed stalks were 12 to 18 inches tall.

Chemicals tested at 1 to 3 rates in applications made at bolting time in two or three experiments included 2,4–dichlorophenoxyacetic acid (2,4–D) in finely ground wettable powder form, 3–(p-chlorophenyl)-1, 1–dimethylurea (CMU), sodium dichlorophenoxyethyl sulphate (SES) and sodium pentachlorophenate (NaPCP). These chemicals are designated by the generally accepted symbols in tables 1 and 2 and elsewhere in this paper. Amine and ester formulations of 2,4–D were tested in the 1951 experiment but caused such severe damage to onions that they were omitted from the 1952 and 1953 experiments.

The herbicides were applied with a constant-pressure sprayer at 30 p.s.i. immediately after the crop had been given the final cultivation and the land had been furrowed for subsequent irrigation. The spray applications were made between the rows of onions in such a way as to cover all the soil surface, but the spray was allowed to hit only the basal 2 to 3 inches of the plant—that portion protected by a sheath just above the bulb and below the leaves. The spray applications were made when there was little or no air movement and no spray shields were used. Such shields would be desirable, perhaps even necessary, in commercial spray applications. The herbicides applied as just described constituted pre-emergence treatments on weeds but postemergence applications in the onions.

Since the occurrence of rain immediately following the application of herbicides in 1950 and its lack in 1951 seemed to influence the ultimate results, an overhead sprinkle irrigation (to simulate rain) of 1 to 1.25 inches was given to one series of treatments within a split-plot experiment in 1952 and 1953. An identical series was left unsprinkled. Fortunately in these years rain did not occur for several weeks. Both the sprinkled and unsprinkled series were surface irrigated as soon as the need for such irrigation was indicated.

The excellent control given by some herbicides in the early years indicated that perhaps weeds could be controlled during the entire growing season by application of herbicides immediately following the setting out of the mother bulbs in the spring. Consequently, in 1951 and thereafter a third series of onion plots was furrowed for irrigation immediately after planting and received such early treatments. In addition to CMU, 2,4–D acid, and NaPCP, isopropyl N(3–chlorophenyl) carbamate (CIPC) was included in these early spring treatments. Subsequently the soil was not disturbed or, if necessary, was hoed only deeply enough to cut off all weeds that survived the chemical treatments.

In 1950, 1951, and 1953 the experiments were conducted on a Sterling loam; and in 1952 on a Millville gravelly loam. All of the experiments were in the vicinity of Logan, Utah.

The Sweet Spanish variety was used in all experiments except in 1953, when White Portugal was planted. Treatments in all series were replicated four times, except in 1952, when a shortage of bulbs permitted only two replications. The plot harvested for seed yields consisted of two rows, each 20 feet long, or a total of 80 plants, when there was a full stand. The criteria for measuring results were plant counts or stand estimates of broad-leaved weeds and grasses and the yield of onion seed.

The stand of annual weeds on untreated checks was extremely dense in 1951, moderately dense in 1952 and quite sparse in 1953. The number of weeds per square foot ranged from more than 100 in late summer of 1951 to only 7 in early spring 1953 and 3 in late summer of 1953. For this reason stands of weeds are expressed as percentage of untreated check in tables 1 and 2. The weed population in summer consisted chiefly of rough pig weeds *(Amaranthus retroflexus)*, prostrate pigweed *(A. graecisams)*, and green foxtail *(Setaria viridis)*. In spring pigweeds, tumbling mustard *(Sisymbrium altissimum)*, and other mustards and wild oats *(Avena fatua)* were the principle weeds present.

RESULTS AND DISCUSSION

Treatments at Time That Bolting Began

Each of the four chemicals, CMU, 2,4–D acid (wettable powder), SES, and NaPCP, tested for weed control at the time the onions began to bolt gave rather promising results in one or more years (table 1). All four chemicals gave good to fair control of broad-leaved weeds in most instances and all gave better control when the treatments were followed immediately by a sprinkle irrigation in 1952 and 1953 than when no sprinkle irrigation was given. The stand of broad-leaved weeds ranged from 0 to 24 per cent of that in the control plots of the sprinkled series, but in the unsprinkled plots weed stands were usually noticeably greater.

The survival of weed grasses after different treatments ranged from 7 to 49 per cent of the check stand on sprinkled plots and 30 to 117 per cent of the check stand on unsprinkled plots. CMU at 2 pounds per acre permitted the survival of 30 to 72 per cent of grasses on unsprinkled plots. However, where stands of weed grasses are dense, even 70 per cent control would not be sufficient.

No effective rainfall occurred soon after the chemical treatments and before furrow irrigation in any of the 3 years. A total of 1.75 inches of rain fell 3 weeks after treatment in 1952; however, this was after the first furrow irrigation. In 1953 no rain at all fell after treatment, and the better weed control on sprinkle-irrigated plots was even more marked than in 1952.

CMU consistently gave the best control of both broad-leaved weeds and grasses. CMU at 1 pound per acre usually was slightly

Table 1. Stands of weeds and yields per acre of recleaned onion seed on plots treated with herbicides between the rows of onions just beginning to bolt.

Irrigation and kind of herbicide	Amount of herbicide per acre	Stand of annual broad-leaved weeds*			Stand of annual grass weeds*			Yield of recleaned onion seed		
		1951	1952	1953	1951	1952	1953	1951	1952	1953
	Lbs.	*Pct.*			*Pct.*			*Lbs.*		
Sprinkle irrigation immediately after treatment										
2,4-D acid**	2	—	—	8	—	—	24		—	871
2,4-D acid	3	—	14	8	—	43	30	—	440	806
2,4-D acid	4	—	—	16	—	—	28	—	—	819
SES	2	—	—	21	—	—	24	—	—	819
SES	3	—	23	—	—	40	—	—	472	—
SES	4	—	—	24	—	—	24	—	—	823
CMU	1	—	13	5	—	20	24	—	366	802
CMU	2	—	4	13	—	7	14	—	405	632
CMU	3	—	—	0	—	—	10	—	—	488
NaPCP	30	—	—	24	—	—	49	—	—	780
None (unweeded)	–	—	100	100	—	100	100	—	353	862
No sprinkle irrigation										
2,4-D acid	2	—	—	22	—	—	117	—	—	845
2,4-D acid	3	30	24	33	96	109	100	454	405	849
2,4-D acid	4	—	—	18	—	—	74	—	—	889
SES	2	—	—	40	—	—	81	—	—	880
SES	3	—	26	—	—	56	—	—	318	—
SES	4	—	—	18	—	—	81	—	—	819
CMU	1	—	26	18	—	50	82	—	366	675
CMU	2	14	3	33	35	30	72	529	407	662
CMU	3	—	—	0	—	—	36	—	—	561
NaPCP	30	23	—	89	116	—	71	504	—	802
None (unweeded)	–	100	100	100	100	100	100	581	274	841
Standard error of the difference between treatment means within the same method of sprinkling:								41	—	47

*Per cent of stand on unweeded control plots.
**Finely ground wettable powder form.

more effective than either 2,4–D acid or SES at 2 to 4 pounds per acre, while CMU at 2 or 3 pounds per acre gave much better weed control. SES tended to be less effective than 2,4–D acid at equivalent rates. NaPCP at 30 pounds per acre gave fair control of broad-leaved weeds under favorable conditions but was definitely less effective than either CMU or 2,4–D acid.

Onion seed yields were reduced somewhat by all chemical treatments in 1951 but were increased or at least not reduced in 1952. Yields were not noticeably affected in 1953 by either 2,4–D acid or SES. However, CMU showed a definite tendency to reduce onion seed yields, especially at rates of 2 and 3 pounds per acre, some reductions amounting to as much as 44 per cent. CMU at 1 pound per acre reduced yields 7 to 20 per cent. Perhaps the fact that the White Portugal variety of onion was used in the 1953 experiment, whereas the Sweet Spanish variety was used in 1951 and 1952, may account for part of the difference in injury caused by CMU. It would appear that with the White Portugal variety 1 pound per acre of CMU is about the maximum rate that can be used safely for weed control.

NaPCP showed a tendency to reduce onion seed yields slightly in both 1951 and 1953. Since this chemical was less effective in controlling weeds, it appears less promising than either CMU or 2,4–D acid.

Treatments at Time of Planting

As was indicated earlier, the attempt to control weeds throughout the growing season by an initial application of herbicides immediately after the mother bulbs had been set out and covered was suggested by the encouraging results obtained in some instances from treatments made at the time bolting began. In these latter studies, which began in 1951, excellent weed control was obtained, but some of the effective herbicides caused greater reduction in onion seed yields than when they were applied only after bolting began.

As is shown in table 2, most of the chemical treatments gave excellent early-season control in 1951 and 1953, the stand of weeds in most instances ranging from 0 to 20 per cent of untreated checks. In 1952, the weed control early in the season was much less satisfactory, probably because no rainfall occurred until a month after the chemical treatments, when a series of light showers totalled 0.86 of an inch. About 2 months after treatment, another series of showers totalled 1.75 inches. These rains, especially the latter, apparently carried the chemicals into the soil, as much better weed control resulted thereafter.

Table 2. Stands of weeds and yields per acre of recleaned onion seed on plots treated with herbicides in early spring immediately after mother bulbs were covered.

Kind of herbicide	Amount of herbicide per acre	Stand of annual broad-leaved weeds*						Stand of annual grass weeds*						Yield of reclean onion seed		
		May 29 1951	June 27 1951	May 29 1952	July 3 1952	May 28 1953	July 21 1953	May 28 1951	June 27 1951	May 29 1952	July 3 1952	May 28 1953	July 21 1953	1951	1952	1953
	Lbs.	*Pct.*						*Pct.*						*Pct.*		
2,4-D acid**	3	8	28	—	—	0	113	41	133	—	—	1	74	202	—	497
CMU	1	—	—	45	30	12	34	—	—	107	35	11	53	—	366	780
CMU	2	2	1	19	6	10	21	0	0	70	44	3	40	531	385	523
CMU	3	—	—	—	—	0	13	—	—	—	—	3	26	—	—	209
NaPCP	30	10	16	—	—	0	26	61	33	—	—	16	76	456	—	605
CIPC	6	—	—	—	—	30	40	—	—	—	—	18	76	—	—	825
CIPC	12	—	—	—	—	18	87	—	—	—	—	19	47	—	—	889
None	—	100	100	100	100	100	100	100	100	100	100	100	100	491	396	745
Standard error of the difference between treatment means within the same method of sprinkling:														41		57

*Per cent of stand on unweeded control plots.
**Finely ground wettable powder form.

Conditions were favorable for good weed control early in 1953, as frequent showers occurred beginning only a few day after the chemical treatments were applied and totalled 5.21 inches prior to bolting of onions. However, later in 1953 weed control by most of the treatments was unsatisfactory. In 1951, the first rain did not occur until 18 days after treatment but the total that fell before bolting of onions was 4.75 inches. Weed control was not quite as good early in 1951 as in 1953, but later in 1951 the results from the various treatments were much better than in 1953. The reason for these differences may have been that rains began nearly 3 weeks later and totalled slightly less in 1951.

As in the treatments made when onions began to bolt, CMU gave better weed control than other herbicides. CMU apparently remained active in the soil longer and gave much better weed control later in the season. CMU at 1 and 2 pounds per acre did not cause important reductions in onion seed yields in 1951 and 1952. The 1-pound rate caused no reduction in yield in 1953, but the 2- and 3-pound rates reduced onion seed yields 30 and 72 per cent, respectively, as compared with the untreated control.

Both 2,4–D acid and NaPCP gave satisfactory early-season control of broad-leaved weeds and grasses in 1953 and of broad-leaved weeds in 1951. However, neither chemical was effective on grasses in 1951 and neither remained active in the soil long enough to give satisfactory weed control during the summer (table 2). Onion seed yield was reduced severely by 2,4–D acid in both years. NaPCP did not reduce onion seed yields noticeably in 1951 but reduced the yield 16 per cent in 1953.

CIPC was less effective than the other chemicals in 1953 but still reduced the weed population 70 to 80 per cent early in the season. Onion seed yields were higher for both rates than for the nonchemical control. No explanation for these yield increases is known.

The yield results indicate that 2,4–D acid definitely cannot be used safely for weed control in bulb-to-seed onions early in the season and that the use of NaPCP is of doubtful value. CMU apparently can be applied safely early in the season at 1 pound per acre, but the 3-pound rate is definitely too hazardous and the 2-pound rate is likely to cause injury in some years. One year's results indicate that CIPC can be used safely, even at heavy rates. The results to date would appear to justify testing CIPC at a heavy rate or CMU at 1 pound per acre immediately after setting out the mother bulbs, and following it by either 2,4–D acid or SES at 3 pounds per acre or CMU at 1 pound per acre at bolting time.

SUMMARY

Weeds cause serious losses in seed onions and are difficult, if not impossible, to control by mechanical or handweeding methods after bolting begins because of breakage of or injury to the brittle seed stalks.

Each of 5 different herbicides tested at Logan, Utah, during 1951 to 1953 gave effective control of annual weeds under certain conditions without reducing seed yields. Good weed control resulted with few exceptions only when adequate rainfall or a sprinkle irrigation occurred soon after application of the chemicals.

The most promising treatments for application at the bolting stage of onions were 2,4–D (wettable powder) at 3 or 4 pounds per acre, SES at the same rates, and CMU at 1 and 2 pounds per acre. CMU at 1 and 2 pounds per acre and CIPC at 6 and 12 pounds per acre gave promising results when applied immediately after onion bulbs were planted in early spring.

Some Effects of Post-emergence Applications of Dalapon to Wild Oats[1]

ROBERT N. ANDERSEN and E. A. HELGESON, *Field Crops Research Branch, A.R.S., U.S.D.A., and North Dakota Agr. Exp. Sta., Fargo, N. D.*

PROMISING results of applications of α, α-dichloropropionic acid (Dalapon) to wild oats *(Avena fatua)* were first reported in May 1953 in Dow Chemical Company's Dalapon Bulletin No. 1. Encouraging results with Dalapon on wild oats were obtained by various workers during the summer of 1953. The work reported herein was conducted in 1954 to gain further information on the effects of Dalapon on wild oats.

Wild oats seed was drilled approximately 3 inches deep into a Fargo clay soil at Fargo, N. D. early in the spring of 1954. Plots 3½ x 18 feet were laid out in a split plot design with 4 replications. Stages of growth when treatments were applied were main plots and rates of Dalapon were subplots. Dalapon as the sodium salt (with wetting agent included in the formulation) was applied in 40 gallons of aqueous solution per acre using an experimental sprayer carried on the back.

Applications were made when the wild oats were in the seedling, early tillering, fully tillered, and boot stages of growth. Different plots were sprayed at these stages so that in no case was any plot treated more than once.

Applications in the seedling stage were made May 17, 1954 when the wild oats were in the one leaf stage, and were 2–3 inches tall. Soil surface moisture was adequate. The temperature had dropped to 30° F. during the preceding night but had risen to 52° F. at time of spraying. The average daily minimum temperature for the week following treatment was 43° F.; the average daily maximum was 73° F. No precipitation occurred for 6 days after treatment.

Applications in the early tillering stage were made May 29, when the wild oats had an extended height of 4 to 6 inches. Surface soil was quite moist from a recent rain. The temperature had dropped to a low of 38° F. during the preceding night and had risen to 65° F. at time of spraying. The average daily minimum temperature for the week following treatment was 42° F.; the average daily maximum was 63° F. A very light rain fell about 26 hours after treatment.

On June 12 the wild oats were fully tillered. Each plant had approximately 4 tillers. The extended leaf height was 12 to 14 inches. Applications on this day were made early in the morning while the vegetation was wet with dew. Surface soil was moist from recent rains. The low during the preceding night was 55° F. The temperature was 59° F. at spraying time. The average daily minimum temperature for the week following treatment was 56° F.; the average daily maximum was 81° F. A trace of rain fell about 25

[1]Published with the approval of the Director of the N. D. Agr. Exp. Station.

hours after treatment and 0.37 inch was recorded for the second day after treatment.

The last applications were applied on June 22 when the wild oats were in the boot stage. Some plants were in early boot and a few had heads just starting to emerge. Most plants were in conditions between these two extremes. The extended leaf height was 22 to 27 inches. Soil moisture was adequate. The low the preceding night was 58° F. and the temperature was at 75° F. at spraying time. The average daily minimum temperature for the week following treatment was 59° F.; the average daily maximum was 84° F.

EFFECT ON AMOUNT OF VEGETATION PRODUCED

No apparent effects from any of the rates of Dalapon were noted at the end of the first week. Two weeks after treatments a slight tip burn was noted on all plants treated in the seedling stage and stunting was apparent. Little increase in height occurred after 2 weeks except for a few plants treated with the lower rates that continued to grow and produce a small panicle. Fig. 1 shows typical plants treated in the seedling stage with 4 or 6 pounds of Dalapon as they appeared 6 weeks after treatment. All the plants in Figure 1 were still green. There was a gradual deterioration of most of the plants treated in the seedling stage until effects of treatments were masked by drying of vegetation due to a rust attack.

Plants treated in the early tillering stage showed burning of the leaves within one week's time. The burn was proportional to the amount of Dalapon applied. Very little increase in height was made after treatment. Fig. 2 shows typical plants from plots treated with 4 or 6 lbs. of Dalapon at the early tillering stage of growth. The smaller plant in both cases in Fig. 2 is dead, as were a great many of the plants in the plots. The two plants from each of the treated plots show typical extremes that occurred 6 weeks after treatment.

Treatments in the fully tillered stage did not give quite as much immediate leaf burn as the treatments at the early tillering stage; otherwise the results were similar to the early tillering treatments.

Applications of Dalapon to plants in the boot stage were too late to have much effect on amount of vegetation produced since nearly all the vegetative growth had been completed at time of treatment.

A quantitative measure of control was obtained by determining the oven dry weight of the living shoot material remaining 6 weeks after treatment. This was done by taking 24 plants from each plot, or a total of 96 for a given treatment. The plants in the sample were chosen by placing a marked stick in alternate rows and taking the plant nearest each mark until the desired number of plants was obtained. The plant nearest the mark was taken even if it was living, dead or partly dead. All dead material was discarded and the oven dry weight of only the living portion was obtained. These data are presented in Table 1.

It was impossible to secure data for the last two stages of growth by this method, since 6 weeks after those treatments were applied even the checks contained much dead material due to a rust attack.

Figure 1. Wild oats plants treated in the seedling stage with Dalapon. The check is represented by a single plant. The two rates of Dalapon are represented by two plants each which show the typical extremes found in the treated plots. Photo 6 weeks after treatment. Ruler is 18 inches long.

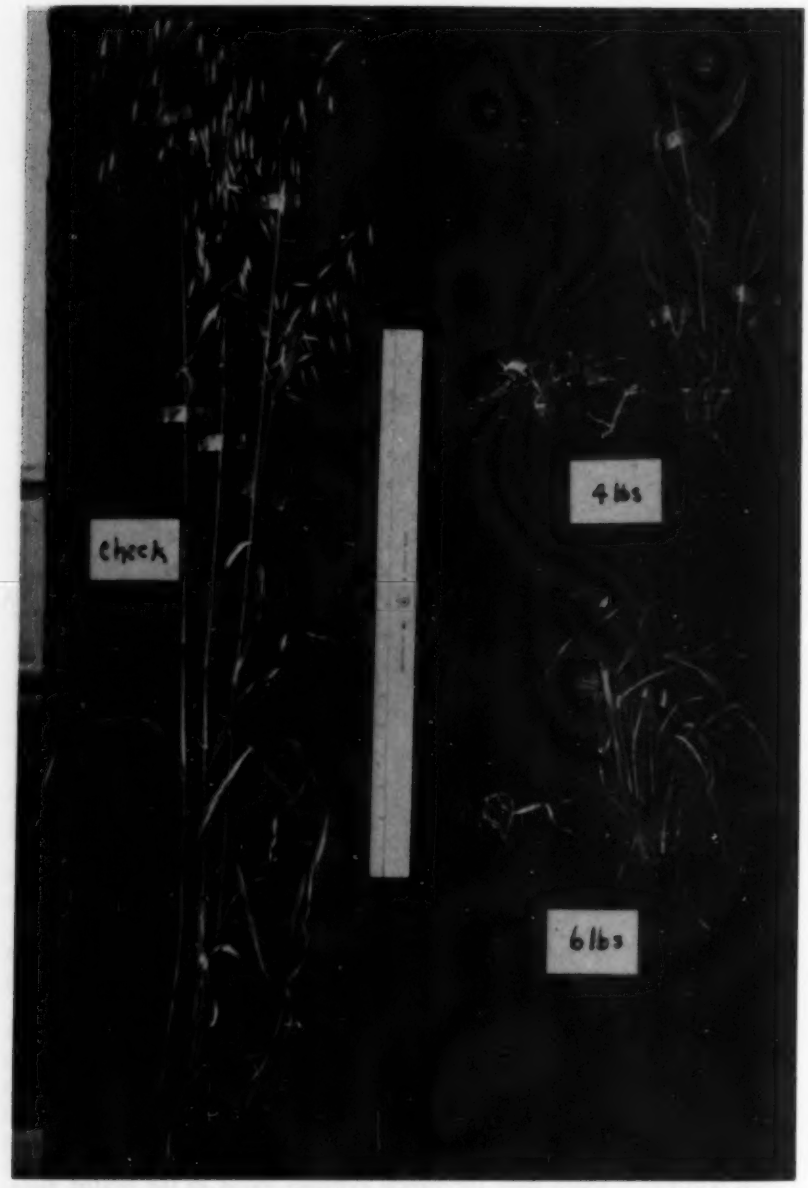

Figure 2. Wild oats plants treated in the beginning tillering stage with Dalapon. The check is represented by a single plant. The two rates of Dalapon are represented by two plants each which show the typical extremes found in the treated plots. Photo 6 weeks after treatment. Ruler is 18 inches long.

Table 1. Oven dry weights of living shoot material of wild oats six weeks after treatment with Dalapon at various rates and various stages of growth, 1954.

Treatment†	Oven dry weight of the living shoot material of 96 plants* 6 weeks after treatment and percentage control based on the check					
	Seedling stage		Early tillering stage		Fully tillered stage	Boot stage
	Grams	%	*Grams*	%		
Check	262	0	395	0		
Dalapon 4 lbs./A.	127	52	19	95		
Dalapon 6 lbs./A.	116	56	15	96		
Dalapon 8 lbs./A.	68	74	6	98	Data not obtained	
Dalapon 12 lbs./A.	58	78	4	99	See text for explanation	
Dalapon 16 lbs./A.	40	85	7	98		

*Figure represents the combined weight of a sample of 24 plants taken from each of 4 replications.
†Rates are acid equivalent.

As seen in Table 1, excellent control of wild oats was obtained with applications in the early tillering stage with Dalapon at rates as low as 4 and 6 pounds per acre. No explanation for the superiority of treatments in the early tillering stage over treatments in the seedling stage is apparent. Possibilities include: greater resistance inherent in seedling stage, possible emergence of some plants after treatment, and different environmental conditions associated with each stage.

Although no quantitative data were obtained, control from treatments in the fully tillered stage appeared to about equal treatments in the early tillering stage.

Effect on Tiller Production

The average number of tillers per plant was determined by counting tillers on 96 plants from each treatment (24 plants from each of the 4 replications). For the first two stages of growth, the plants used were the same ones used in determining the weight of living matter shown in Table 1. The plants for tiller counts from the last two stages of growth were selected in the same way as for the first two stages of growth. This method is described above. In making tiller counts both living and dead tillers were included. All tillers regardless of size were included.

These data reported in Table 2 were analyzed statistically considering each stage of growth separately. The analysis then became that of 4 randomized block experiments.

Table 2 shows that Dalapon caused a highly significant increase in numbers of tillers produced. This occurred at all rates and stages studied.

Practically all the tillers on plants treated in the seedling stage were living 6 weeks after treatment. Those from plants treated in the early tillering stage had only 19% to 32% living tillers 6 weeks after treatment. The percentage of living tillers could not be determined for the last two stages since rust had masked the treatment effect, and even the checks had much dead material.

It is particularly interesting to note in the last two columns of Table 2 the increase in tillering in plants treated after the tillering process was normally completed.

Table 2. Effect of Dalapon at various rates and stages of growth on tiller production in wild oats, 1954.

Treatment†	Average number of tillers per plant 6 weeks after treatment*			
	Seedling stage	Early tillering stage	Fully tillered stage	Boot stage
	No.	No.	No.	No.
Check	4.2	3.7	3.6	3.3
Dalapon 4 lbs./A.	10.8**	10.9**	13.6**	5.4**
Dalapon 6 lbs./A.	18.8**	11.2**	13.2**	5.2**
Dalapon 8 lbs./A.	19.9**	11.1**	14.2**	5.4**
Dalapon 12 lbs./A.	19.7**	11.3**	12.3**	5.2**
Dalapon 16 lbs./A.	19.5**	13.3**	14.8**	5.2**
L.S.D. P = 1%	4.0	2.8	3.3	1.5

*Figure represents the mean number of both living and dead tillers from a sample of 24 plants taken from each of 4 replications.
†Rates are acid equivalent.
**Indicates a significant difference from the check at the 1% level of probability.

The appearance of plants with increased numbers of tillers for the first two stages of growth may be seen in Figures 1 and 2.

Effect on Heading

In some cases it is possible that the prevention of seed production in wild oats would in itself be sufficient control. In order to determine the effects of Dalapon on heading, all plots were visually compared to the check at maturity. The data thus obtained are reported in Table 3. As seen in Table 3, control of heading from treatments in the seedling stage was better than control using weight of living material 6 weeks after treatment (Table 1) as the criterion. Control of heading from treatments in the early tillering or fully tillered stage was excellent. Some control of heading resulted from applications in the boot stage. This contol however was mostly a retarding of elongation of the flowering stalk, leaving the panicle partially or completely enclosed in the boot.

Effect on Viability of Seed Produced

Since applications of Dalapon in the boot stage failed to control heading effectively, the viability of the seed produced by plants treated in the boot stage was tested. Shortly after maturity when

Table 3. Percentage control of heading of wild oats treated with Dalapon at various rates and various stages of growth, 1954.

Treatment†	Percentage control of heading based on visual comparison to check*			
	Seedling stage	Early tillering stage	Fully tillered stage	Boot stage
	%	%	%	%
Check	0	0	0	0
Dalapon 4 lbs./A.	78	99	97	22
Dalapon 6 lbs./A.	92	100	99	32
Dalapon 8 lbs./A.	98	100	99	36
Dalapon 12 lbs./A.	99	100	100	36
Dalapon 16 lbs./A.	100	100	100	40

*Data are the mean of percentage control for 4 plots. Percentage control for each plot is the mean of independent estimates of two persons.
†Rates are acid equivalent.

seed was beginning to shatter, samples of seed were collected from all the plots involved in the boot stage treatments. In each plot 100 seeds were collected from the plants and 100 seeds were collected from the ground. Only the primary oat was selected for the sample taken from the plant. In taking the sample from the ground no attempt was made to distinguish between primary and secondary oats, although in most cases the secondary oat was attached to the primary oat. When this occurred the secondary oat was discarded, hence only a very few secondary oats were included in the sample of seed which had shattered to the ground. The seeds were stored dry at room temperature and germinated between moist filter papers in large Petri dishes at 68° F. Germination tests were started 45 days after collection. Only 2 of the 4 replications were tested. The data are shown in Table 4. The first column in Table 4 shows that Dala-

Table 4. Germination of seed from wild oat plants treated in the boot stage with Dalapon, 1954.

Treatment†	Germination of un-shattered seed*		Germination of shattered seed*		Germination of both combined
	3 days in germinator	14 days in germinator	3 days in germinator	14 days in germinator	14 days in germinator
	%	%	%	%	%
Check	34.5	47.0	17.5	40.5	43.8
Dalapon 4 lbs./A.	1.5	28.5	7.5	36.0	32.2
Dalapon 6 lbs./A.	0.5	38.5	16.5	51.5	45.0
Dalapon 8 lbs./A.	0.5	26.5	7.5	53.0	39.8
Dalapon 12 lbs./A.	0.5	42.0	14.5	62.0	52.0
Dalapon 16 lbs./A.	1.5	40.5	11.0	49.0	44.8

*Figures represent mean of two lots of 100 seeds each.
†Rates are acid equivalent.

pon caused a definite initial retardation of germination in the samples of seed collected from the plants. These seeds had not yet shattered, and would supposedly be younger than the shattered seeds at time of treatment. This retarding effect did not continue as can be seen in Table 4, for after 14 days in the germinator all the seeds from the treated plots had germinated in amounts comparable to the check.

Initial retarding of germination due to treatment was not noted in seed taken from the ground. For as seen in the third column, the seed from the treated plots germinated quite well as compared to the check. The check from the ground showed a retarded germination as compared to the check from the plants.

Considering the total germination (last column, Table 4) it is seen that Dalapon did not effectively reduce the viability of the wild oat seed produced.

Since some effect of treatment was noted, i.e. an initial retardation of germination in seeds taken from treated plants, it is planned to plant the seeds from the 2 remaining replications and observe the seedlings produced.

SUMMARY

In this study conducted at Fargo, N. D. in the growing season of 1954 the following results were obtained:

(1) Dalapon at rates as low as 4 and 6 pounds acid equivalent per acre effectively controlled vegetative production in wild oats particularly when applied at the early tillering and fully tillered stages of growth.

(2) Application of Dalapon increased tiller production in wild oats even when applied after the plants had ceased normal tillering.

(3) Dalapon at rates as low as 4 and 6 pounds acid equivalent per acre effectively controlled heading of wild oats when applied from the seedling stage up to and including the fully tillered stage.

(4) Applications of Dalapon in the boot stage showed no promise of effectively controlling viable seed production in wild oats.

The Response of Certain Crops to 2,4–Dichlorophenoxyacetic Acid in Irrigation Water[1]

Part 1. Red Mexican Beans

V. F. Bruns[2]

Introduction

Numerous investigations in which crop plants were utilized to study the effect, persistence, and movement of spray residues of 2,4–dichlorophenoxyacetic acid (2, 4–D) in a variety of soils and under a wide range of conditions have been reported. However, except for a report by Arle (1), a search of the literature has revealed no direct information on the effects of 2,4–D when applied in irrigation water to crop plants growing in the field. Arle treated cotton with irrigation water containing 2,4–D in equivalents ranging from 0.5 to 8 pounds per acre. Significant decreases in yield usually resulted from the higher rates of treatment when applications were made early in the season. Applications at the lower rates usually resulted in yields about equal to or greater than those obtained from check plots.

Oborn and Bartley (7) conducted similar studies in the greenhouse. Plants were grown in pots containing a mixture of one-third sand, one-third top soil, and one-third Michigan peat by volume. Water containing different concentrations of 2,4–D was applied daily for several weeks. The total quantities of 2,4–D which were applied without serious injury to cotton and tomatoes in these experiments were phenomenal.

The reports of several other workers are of somewhat parallel interest. DeRose (2) found 2,4–D in the leachate from a soil contaminated with this compound. In addition, he found that, under greenhouse conditions, 2,4–D did not remain active in unleached soil for longer than eight weeks and did not persist in soil under field conditions for more than eighty days after treatment. Hanks (4) mixed 2,4–D with six different soils and leached each soil with water at rates equivalent to a total of ten and sixteen surface-inches over a six-week period. Corn-seed bio-assays indicated that the leachates from peat soil were relatively non-toxic at the end of two weeks and that those from all soils, except one naturally alkaline, were relatively free of the herbicide at the end of six weeks.

The sodium salt of 2,4–D applied on the surface of a calcareous soil with a high organic content at the rate of five pounds per acre by Muzik *et al.* (6) did not move beyond the first inch regardless of

[1]Contribution of the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Washington Agricultural Experiment Stations cooperating. Scientific Paper No. 1371, Washington Agricultural Experiment Stations.

[2]Associate Agronomist, Field Crops Research Branch, Agricultural Research Service, Irrigation Experiment Station, Prosser, Washington.

the amount of artificial rainfall applied (one-fourth, one-half, or one inch) or whether the soil was saturated or relatively dry. Hernandez and Warren (5) applied four pounds of 2,4–D per acre to the surfaces of a peat, a silt loam, and a sandy loam soil in the greenhouse. Four surface-inches of water leached the 2,4–D to a depth of only three inches in the peat soil but readily leached the material to the five inch depth in the other soils.

According to Elle (3), the effect of spray residues of 2,4–D (one pound per acre equivalent) in soil, when leached into the root zone of sweet corn seedlings (one-fourth acre-inch of water applied on surface twice daily for a period of three days), was very marked and significantly reduced the total subsequent development of the plants. The effect of the residues on older plants was found to be slight.

The use of 2,4–D for weed control in irrigated regions, especially on ditch banks, provides possibilities of contaminated irrigation water. The purpose of these investigations was to determine the effect of 2,4–D in irrigation water, particularly at rates totaling herbicidal dosages, on certain crop plants. This is a report of the first in a series of such investigations.

MATERIALS AND METHODS

These investigations were conducted on land that had produced no crop since 1923. Previous to 1923, a few non-irrigated crops of rye had been grown. From 1923 to the time these investigations were started, the ground cover was predominantly cheatgrass *(Bromus tectorum* L.). The soil type was Sagemoor very fine sandy loam, low in organic matter, with a depth of sixty inches to bed rock.

After applying 436 pounds of ammonium nitrate (33 percent nitrogen) per acre on June 11, 1951, the land was plowed, harrowed, ditched, and irrigated. Two days after irrigation, the soil was conditioned by the use of spring-toothed and spike-toothed harrows.

On June 16, 15 plots (five plots within three blocks), 10 x 20 feet in size, were laid out on contour with a zero grade. The borders of adjacent plots were at least 36 inches apart while the alleyways between blocks were 10 feet wide (Figure 1). Beans *(Phaseolus vulgaris* L. var. Red Mexican) were planted with a hand planter in rows 24 inches apart and 20 feet long (4 rows per plot). The beans began to emerge on June 22 after which the plants were thinned to one for every three to four inches in the row.

In preparation for irrigation and 2,4–D treatment, hand tools were used to create furrows (approximately 4 inches deep) between the rows of beans on all plots. The plots were squared and the furrows were dammed at each end.

Four 600-gallon metal tanks were used throughout the experiment for applying irrigation water and 2,4–D. Water, as well as the 2,4–D, was measured into the tanks in the desired quantities. To avoid contamination of water applied to untreated plots, two tanks were reserved for making the 2,4–D treatments while the remaining two tanks were used for applying regular irrigation water.

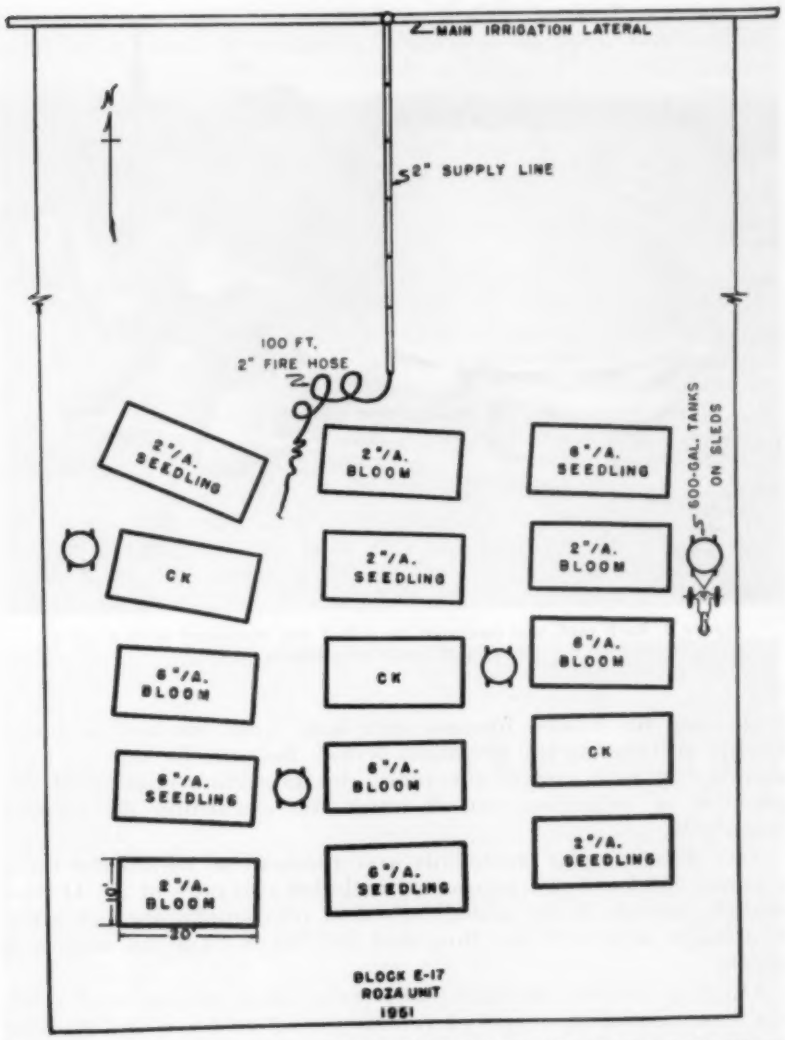

Figure 1. A diagrammatic illustration of the field layout for these investigations.

Each tank was mounted on a sled which could be moved conveniently with a tractor from one plot to another. Each tank was equipped with a valve, hose, and boom attachment. The booms were constructed from 1-inch water pipe and were 10 feet long (Figure 2). Four holes, one-fourth inch in diameter and spaced 24 inches apart, were drilled in a straight line in the pipe. When making applications, the booms were leveled across the ends or middle of the plots to facilitate an equal flow of water into each furrow. By

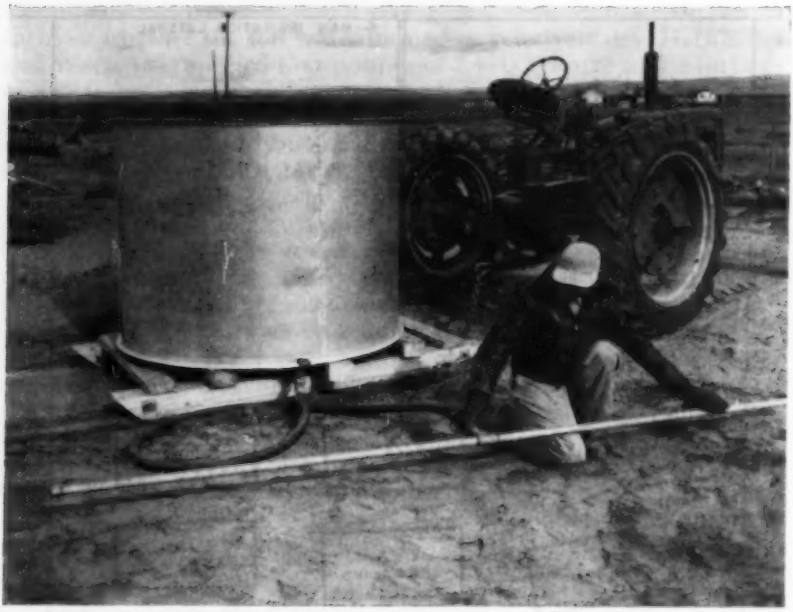

Figure 2. Each tank was mounted on a sled and equipped with a valve, hose, and boom attachment.

regulating the valves, furrows were kept from one-half to three-fourths full during the irrigation period. Because the furrows were dammed at each end of the plots, this procedure eliminated the problem of measuring run-off water and discarding the effluent (Figure 3).

Five different plot treatments were randomized within the three separate blocks. These treatments included two rates of 2,4–D (two and six pounds of the acid dissolved in triethanolamine per acre), two stages of growth (seedling and full-bloom), and an untreated check.

On July 2, when the bean plants were just beginning to develop the first trifoliolate leaves (hereinafter referred to as the seedling stage), the first 2,4–D treatments were made at rates of two pounds and six pounds per acre in three acre-inches of irrigation water. Plots treated at the seedling stage received normal irrigation during the remainder of the season (3 acre-inches on July 13, July 25, August 8, August 28, and September 17). Hand tools were used to work the soil on the plots, simulating normal cultivation.

Plots scheduled to receive 2,4–D treatments during the blossom stage were handled normally until August 8 (3 acre-inches of irrigation water on July 2, July 13, and July 25). At this time, bean plants were in full-bloom and the 2,4–D was applied. The same procedures, methods, and materials were used in making these applications as

were used in making the treatments during the seedling stage. In addition, one-half of each plot, chosen at random, was trellised (Figure 4). Leaves were prevented from hanging in the ditches on the trellised halves of the plots while allowed to remain suspended in the ditches on the non-trellised halves during the irrigation treatments. This offered an opportunity to study the effects of possible leaf adsorption as well as root adsorption of 2,4–D in the irrigation water by the bean plants. The plots received normal irrigations during the remainder of the season (3 acre-inches on August 28 and September 17).

On August 22, plant foliage on all plots was sprayed with a zinc solution in order to eliminate a possible zinc deficiency factor.

Observations on the effects of the 2,4–D treatments on both foliage and roots were recorded throughout the season. On October 4, the entire vine growth on each plot was removed and placed in forced-air drying rooms with temperatures not exceeding 85° F. until all materials were dried uniformly. The material was then threshed to determine dry bean yields.

As a supplement to these studies, both greenhouse and laboratory tests were conducted to determine the effects of the 2,4–D treatments on the germination of the bean seeds and subsequent growth. In the greenhouse tests conducted in March, 1952, duplicate samples of 10

Figure 3. Booms were leveled across the plots and furrows were kept from one-half to three-fourths full during irrigations. A 2,4–D treatment during the seedling stage is pictured.

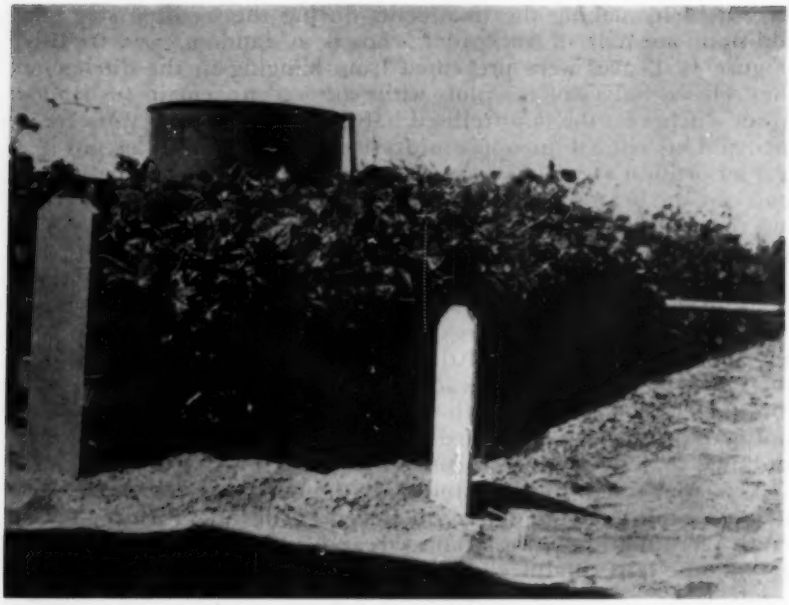

Figure 4. Leaves and vines on one-half of each plot were prevented from dangling in the treated water during the bloom stage applications by the use of trellises.

seeds each were selected for uniformity and soundness from the lots harvested from each field plot, collectively resulting in six replications for each experimental treatment. These seed samples were placed in separate 6-inch clay pots containing Sagemoor fine sandy loam soil. The percentage germination of seed was noted and the development of plant growth was observed until the plants had reached an advanced stage of blooming.

In May, 1952, bean seeds totaling 1000 per field treatment (333–334 from each replicate plot) were subjected to the regular seed analytical tests at the Idaho State Seed Laboratory, Boise, Idaho. Determinations included the percentage of seeds which were abnormal, dead, and broken, and possible chemical injury to the seeds.

EXPERIMENTAL RESULTS AND DISCUSSION

Within one week after the 2,4–D was applied in irrigation water to the beans in the seedling stage on July 2, definite inhibition of plant growth, especially terminal leaf growth, was noted. Plants on untreated check plots were more succulent and growing more rapidly than those on treated plots and averaged approximately one inch taller in growth. Leaves of plants on treated plots were much darker green in color than those on check plots. Distortion of stems and leaves, the characteristic reaction when 2,4–D is applied to the foliage of beans, was not in evidence.

After 10 days, inhibition of plant growth was more pronounced on all plots treated with 2,4–D. A few plants appeared dead on plots treated at six pounds per acre. Terminal growth appeared seriously damaged. Excessive enlargement of stems and nodes, especially near the growing points, was observed (Figure 5).

Sixteen days after treatments, plants appeared to be making some recovery on plots treated with two pounds of 2,4–D per acre. However, nearly all of the plants on the plots treated at six pounds per acre continued to become more chlorotic and were making little, if any, growth. Some plants on the latter plots appeared dead. Many of the leaves of plants on treated plots, especially those which received six pounds per acre, showed pronounced, although varied, types of injury at this time. These included yellowing of the leaves (chlorosis), dwarfing of the leaves, especially terminal leaves, minor distortion or curling of the leaves, discoloration of the leaf veins, and thickening of the inter-veinal tissue with the development of a leather-like texture. Purple pigmentations in the lower leaves were noted on a considerable number of the plants on treated plots. The symptoms of injury to the bean plants actually were quite unlike those obtained from foliage applications of 2,4–D.

By the eighteenth day, plants showed definite recovery on plots which received two pounds of 2,4–D per acre. At that time, approximately 50 pecent as much foliage growth had developed on these plots as on the untreated checks. Some recovery of plants was ap-

Figure 5. Typical response of seedling beans 10 days after application of either two or six pounds of 2,4–D per acre in irrigation water. Note leaf chlorosis, damaged terminal growth, and enlarged stem and nodes.

parent also on plots treated with six pounds per acre, particularly plants which were affected less severely during the initial stages. Examination of the roots of a number of plants showed that considerable portions of the root systems of plants on treated plots had been destroyed. Abnormal root development from adventitious buds was apparent on plants which had received the 2,4–D treatments (Figure 6).

After three weeks, the relative recovery of plants became more

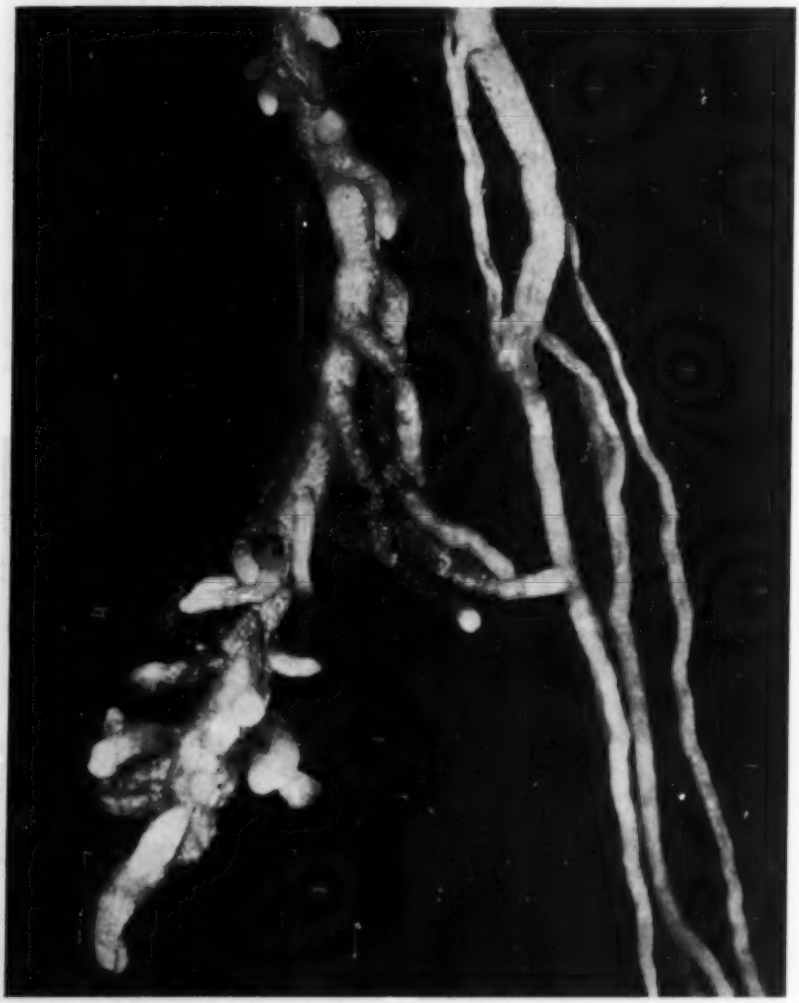

Figure 6. Abnormal development of bean roots 18 days after applying 2,4–D in the irrigation water during the seedling stage. Left: Treated (six-pound rate). Right: Untreated.

noticeable on treated plots, i.e., the recovery on plots treated with two pounds per acre progressed rapidly while that on plots treated with six pounds per acre progressed slowly.

The growth and development of plants on plots which received two pounds per acre appeared to be nearly normal by the twenty-fourth day. Only a few plants, damaged more severely during the early stages, remained in a somewhat stunted condition. Leaves which were present when the treatments were made continued to appear somewhat curled and chlorotic. However, no symptoms of 2,4–D were apparent in the new stem and leaf growth. The difference between the amount of plant foliage produced on plots treated with two pounds of 2,4–D per acre and on the untreated check plots had narrowed considerably.

At the same time, progressive recovery of a number of plants was apparent on plots treated with six pounds per acre, although the greater percentage of the plants remained severely stunted. Chlorosis, distortion, and swelling of the leaves and stems, which developed soon after treatment, were still evident. However, little, if any, 2,4–D injury was apparent in the later growth. The most amazing phenomenon was the development of new growth from many plants which initially had appeared to suffer lethal damage to the foliage and root systems (Figure 7).

Bean plants on the untreated checks began to blossom on July 31, while those on plots treated with two pounds of 2,4–D per acre did not begin to blossom until August 2. Plants did not commence to bloom until August 6 on the plots treated with six pounds per acre, and blooming was restricted to a few of the more vigorous plants. Although growth was noticeably delayed with respect to maturation, the health and vigor of plants on the plots treated with two pounds per acre appeared nearly equal to that of plants on the untreated plots. Further development of terminal growth and further recovery of surviving plants was noted on plots treated with six pounds per acre.

Thirty-nine days after treatment practically all symptoms of 2,4–D injury had disappeared on plots treated at the rate of two pounds per acre and the plants were growing rapidly. Rapid development of the surviving plants was observed also on plots receiving six pounds per acre. Some plants began to fruit on the check and other untreated plots. Plots to be treated during the bloom stage of the beans received the applications of 2,4–D at rates of two pounds and six pounds per acre in the irrigation water.

The root systems of several plants from the plots treated with 2,4–D during the seedling stage were examined 42 days after treatments. Further abnormal root development was revealed. Apparently, most of the original root systems were destroyed by the treatments, especially on plots treated at the rate of six pounds per acre. Plant life was sustained almost entirely by club-like adventitious roots (Figures 8 and 9).

Fruiting was evident on all plots by August 17, even on those plots treated with six pounds of 2,4–D per acre during the seedling

Figure 7. Twenty-four days after the six-pound, seedling-stage treatment, new growth had developed on many plants (as shown) which earlier had appeared to suffer lethal injury to foliage and root systems.

stage. Slight chlorosis of the leaves was noted on plants treated during the bloom stage. No growth differences between the trellised and non-trellised portions of the plots were apparent.

During the period between 51 and 71 days after treatment at the seedling stage and between 12 and 32 days after treatment at the

Figure 8. Representative root systems of bean plants 42 days after the 2,4–D treatments at the seedling stage. Left: Treated (six-pound rate). Center: Treated (two-pound rate). Right: Untreated.

bloom stage, the amount of plant foliage on plots treated with two pounds per acre during the seedling stage appeared almost equal to that on check plots. Nearly all symptoms of 2,4–D injury had disappeared and surviving plants were making lush growth on plots treated with six pounds per acre during the seedling stage. Leaf chlorosis, the only visible symptoms of 2,4–D injury to the foliage, increased gradually on plots treated during the bloom stage. Natural maturation of plants became evident on the check plots by September 11.

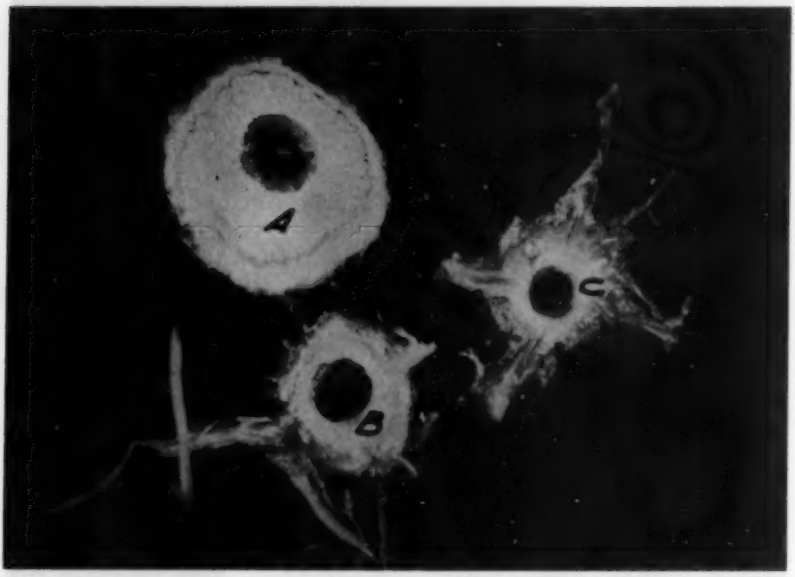

Figure 9. Cross-sections of bean roots pictured in Figure 8. (A) Untreated. (B) Treated (two-pound rate). (C) Treated (six-pound rate).

Natural plant maturity became more noticeable on the check plots by September 17. Some evidence of plant maturation was noted also on plots treated during the bloom stage. No sign of ripening of plants was apparent on plots treated with six pounds of 2,4–D per acre during the seedling stage. However, some leaves of plants began to turn yellow on plots which received two pounds per acre during the same stage.

Although not severe, a late infestation of mosaic was prevalent and appeared to be distributed uniformly over all plots.

A number of plants continued to blossom on check plots and on plots treated with 2,4–D during the bloom stage. Blooming was profuse on plots treated during the seedling stage and many fruits continued to develop.

As a result of the late planting date, the bean plants on the check plots were not fully matured after 110 days, but because of weather and other factors the vines were pulled. Compared with check plots, the maturity of beans was delayed on plots treated with 2,4–D during the seedling stage, especially at the six pound per acre rate, while maturity was hastened to some degree on plots treated during the bloom stage. Delayed maturity and the resulting numerous green pods definitely lowered the quality of beans produced on plots treated during the seedling stage.

Figure 10. Representative root systems of the bean plants at harvest time.

Striking abnormalities of the root systems, including the development of adventitious buds, were noted on plants taken from plots treated with 2,4–D, particularly from plots treated at the rate of six pounds per acre (Figures 10 and 11).

The yields of threshed beans are given in Table 1.

Because split plots were used for the 2,4–D treatments which were made during the bloom stage only, separate analyses of variation were made to determine any significant differences in the yields obtained from the trellised and non-trellised portions of these plots. The analyses of these data are presented in Table 2 and show no significant differences between the yield of beans from trellised and non-trellised plots.

Table 1. The yield of Red Mexican beans as influenced by 2,4–dichlorophenoxyacetic acid in the irrigation water.

Growth stage when treated	2,4-D (lb. per A)	Mean yield (lb. per A)
Seedling	2	2683
Seedling	6	1703
Bloom (not trellised)	2	3060
Bloom (trellised)	2	2661
Bloom (not trellised)	6	2021
Bloom (trellised)	6	1987
Untreated check	0	2829

Figure 11. A close-up of a section of the root system from a bean plant treated at the six-pound rate during the bloom stage. (Photographed at harvest time).

Because no significant differences were apparent, the yields from the trellised and non-trellised portions of each plot were averaged and used as the mean yields for the bloom-stage treatments in the over-all analyses. These analyses are shown in Table 3.

Table 2. Analyses of variation (bloom-stage treatments).

	Mean yield (lb. per A)	
	2 lb. per A treatment	6 lb. per A treatment
Trellised	2661	1987
Not trellised	3060	2021
Sources of variation	D.F.	Mean square
Replicates	2	249,231
Treatments	1	2,200,777
Error	2	118,968
Total treatment plots	5	
Trellising	1	140,617
Trellising vs. treatment	1	100,284
Error	4	91,852
Total	11	

Table 3. Analyses of variation (all treatments).

	Mean yield (lb. per A)	
2 lb. per A seedling stage	2683	
6 lb. per A seedling stage	1703	
2 lb. per A bloom stage	2860	
6 lb. per A bloom stage	2004	
Untreated check	2829	
Sources of variation	D.F.	Mean square
Replicates	2	497,279**
Treatments	4	837,712**
Stage	1	171,602
Rate	1	2,529,090**
Stage × rate	1	11,347
Check vs. treated	1	638,808**
Error	8	46,325
Total	14	

**Significant at 1 percent level.
C.V. 8.9 percent.

The differences in yield among replicates and among treatments were highly significant. In comparison with the check plots, two pounds of 2,4–D per acre applied during the seedling stage and the bloom stage caused no significant reduction in yield of beans. However, the differences between yields from untreated check plots and yields from plots treated with six pounds per acre of 2,4–D during both the seedling and the bloom stages were significant at the one percent level, with 40 and 29 percent reductions in yield from the treated plots, respectively.

In comparing differences among 2,4–D treatments, the rate of six pounds per acre was significantly more detrimental than the rate of two pounds per acre. Although plots treated with two pounds per acre during the seedling stage yielded 177 pounds per acre less beans than plots treated with two pounds per acre during the bloom stage and plots treated with six pounds per acre during the seedling stage

yielded 301 pounds per acre less beans than plots treated during the bloom stage at the same rate, these differences were not statistically significant at the five percent level.

The results of the laboratory tests on the germination of the bean seeds are presented in Table 4 and show no significant differences which could be attributed to the 2,4–D treatments.

Table 4. Results of laboratory germination tests (1000 bean seeds per treatment). May, 1952.

Previous field treatment		Percent (av.)					Apparent chemical injury
2,4-D (lb. per acre)	Growth stage when treated	Germination	Baldheads	Abnormal	Dead	Broken	
2	Seedling	92.8	0.3	4.0	1.5	1.3	none
6	Seedling	94.0	0.3	3.7	1.4	0.7	none
2	Bloom	91.1	0.5	6.3	1.6	0.6	none
6	Bloom	94.0	0.7	2.9	0.9	1.5	none
0	Untreated check	94.0	0.3	4.1	1.0	0.6	none

Note:
(1) Germination: The emergence and development from the seed embryo of those essential structures which are indicative of the ability to produce a normal plant under favorable conditions.
(2) Baldhead: Injury to the epicotyl—no primary leaves orter minal bud—a type of abnormality common in bean seeds.
(3) Abnormal: One or more essential structures lacking or damaged.
(4) Broken: A result of mechanical injury—embryo and cotyledon damaged to the extent that growth is inhibited.

The results of the greenhouse studies on germination of the bean seeds and on the development of the plants are given in Table 5. Bean seeds taken from plots treated with 2,4–D germinated as well as seeds taken from untreated check plots. Plants which developed from these germinated seeds and were held in the greenhouse until well past the initial bloom stage grew normally. No carry-over effects of 2,4–D in the seeds were exhibited.

Table 5. Results of greenhouse germination studies (60 bean seeds per treatment). March–June, 1952.

Previous field treatment		Percent germination	Plant development
2,4-D lb. per A	Growth stage when treated		
2	Seedling	95.0	normal
6	Seedling	98.3	normal
2	Bloom (not trellised)	98.3	normal
6	Bloom (not trellised)	95.0	normal
2	Bloom (trellised)	96.6	normal
6	Bloom (trellised)	96.6	normal
0	Untreated check	93.3	normal

SUMMARY

1. The response of Red Mexican beans to field applications of 2,4–D at two and six pounds per acre in irrigation water during the seedling and bloom stages of growth was studied.
2. The responses of bean plants to 2,4–D in this experiment were notably different from those normally obtained from foliage ap-

plications. The types and degrees of injury noted were: (a) leaf chlorosis; (b) dwarfing of the leaves, especially terminal leaves; (c) only minor distortion or curling of the leaves; (d) discoloration of the leaf veins; (e) thickening of the inter-veinal tissue with the development of a leather-like texture; (f) purple pigmentation in the lower leaves; (g) severe damage to the terminal growing points; (h) excessive enlargement of stems and nodes, especially near the growing points; (i) severe injury to the root systems followed by the development of abnormal club-like adventitious roots; and, (j) general stunting of plant growth.

3. The application of two pounds of 2,4–D per acre in irrigation water during the seedling stage caused pronounced injury to the top-growth and roots of the bean plants. Within 16 days after the application, plants began to recover and no significant reduction in yield resulted.
4. The rate of six pounds of 2,4–D per acre during the seedling stage caused severe damage to the top-growth and destroyed nearly all of the root systems of the plants. Amazingly, within three weeks, a number of plants began to recover with the development of club-like adventitious roots, particularly those injured less severely during the initial stages. Even though maturity was delayed, these plots yielded only 40 percent less beans than untreated checks.
5. Application of two pounds and six pounds of 2,4–D per acre in irrigation water during the bloom stage caused some leaf chlorosis and damage to the root systems and hastened somewhat the maturity of the bean plants. The two-pounds-per-acre treatments caused no significant reduction in yield, but the six-pounds-per-acre applications reduced the yield 29 percent.
6. Laboratory and greenhouse tests exhibited no carry-over effects of 2,4–D in bean seeds harvested from treated plots.

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Chlordane, Chlorobromopropene, and Hexachlorocyclopentadiene for Pre-emergence Control of Crabgrass (*Digitaria sanguinalis* L.) and Other Annual Grasses[1]

C. Dean Dybing, Jess L. Fults, and Roger M. Blouch[2]

Introduction

Crabgrass, the universal lawn weed, has been the object of much research in the past few years. Lawn owners, cotton and vegetable growers, and golf course keepers have long been fighting this pest. Today, chemical eradication is rapidly displacing costly, difficult, and often ineffective mechanical control methods (9).

An ideal crabgrass herbicide would be one which would kill the weed in one application without harming desirable turf grasses or crop plants. The search for such a material has revealed many potential herbicides. Numerous reports have been published concerning the control of crabgrass with sodium arsenite, potassium cyanate, phenyl mercuric acetate, trichloroacetic acid, 0–isopropyl–N–(3–chlorophenyl) carbamate, and 3–(p–chlorophenyl)–1, 1–dimethylurea (1, 3, 4, 8, 9).

These chemicals have given varying results throughout the country, but most of them have had several disadvantages. Some have been too harmful to the turf grasses or crop plants, while others have required costly re-treatments for complete control. Some have proved to be toxic to man and animals, making their unsupervised use hazardous. Almost all have been reported to be ineffective against crabgrass at some stage of growth. A few others are being developed but are not available to the public.

Recently, a material has been tested which, from most reports, appears to be one of the best crabgrass herbicides yet used. This material is the insecticide, chlordane (1, 2, 4, 5, 6, 7, 8, 8–octochloro–4, 7–methano–3a, 4, 7, 7a–tetrahydroindane). It has been reported that chlordane substantially reduces the germination of crabgrass seed (5). This report further states that, when applied post-emergence to lawns in an oil carrier such as kerosene, chlordane gives a rapid kill of crabgrass and chickweed. Its effect on the desirable turf is reported to be slight. Other writers substantiate these facts, reporting that chlordane, besides ridding the turf of ground worms and insects, also shows herbicidal effects against crabgrass (2, 12). A pre-

[1]A contribution from the Botany and Plant Pathology Section of the Colorado Agricultural Experiment Station, Fort Collins, Colorado.

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[2]Research Assistant, Botanist, and Assistant Botanist, respectively.

liminary report by Shaw, Swanson, and Lovvorn (11) indicated that chlordane applied in water as a pre-emergence spray did not produce observable herbicidal or growth effects upon a number of crop plants and weeds, including crabgrass.

This paper presents the results of a greenhouse experiment designed to test chlorobromopropene (CBP), hexachlorocyclopentadiene, and two lots of technical chlordane as pre-emergence crabgrass herbicides.

MATERIALS AND METHODS

Thirty new 13 x 16 x 5 inch greenhouse flats were filled with equal amounts of an unsterilized chocolate-brown mountain alluvial loam soil. The top inch was screened to remove the larger aggregates and foreign materials. The soil was dampened, and the following four grasses were planted separately in rows, ten rows per flat: crabgrass (*Digitaria sanguinalis* L.)—4 rows, foxtail millet (*Setaria italica* L.)—4 rows, green bristlegrass (*Setaria viridis* L.)—1 row, and field sandbur (*Cenchrus pauciflorus* Benth.)—1 row (6). All of the grasses except sandbur were planted at rates calculated, from previous germination tests, to give approximately 100 viable seeds per row. Sandbur was planted at the rate of 25 burs per row. The seeds were covered with about ¼ inch of finely sifted soil. The flats were then treated and watered.

Two replications of fifteen treatments were applied. The following chemicals were tested: (1) 45 percent technical chlordane, 50 percent refined petroleum oil, and 5 percent inert ingredients[1]; (2) 80 percent technical chlordane[2]; (3) chlorobromopropene (CBP), 95 percent concentrate[2]; and (4) hexachlorocyclopentadiene, 90 percent active ingredient[2]. All chemicals were applied at rates of 7½, 15, and 30 pounds per acre of active ingredient. All treatments were applied as water emulsions with a hand sprayer in a volume of 218 gallons per acre. Chlorobromopropene (CBP), was also applied at a rate of 2 gallons of concentrate diluted to 100 gallons per 100 square yards. The 45 percent chlordane, was tested at a rate equivalent to 1 pint per 2000 square feet, (the manufacturer's recommended rate) or 2.13 gallons per acre. This is equivalent to 23 lbs of active compound per acre.

The flats were planted and treated July 13 and 14, 1953. The number of days required for emergence of each species in each flat was recorded. Photographs were taken July 29, about two weeks after planting. Final germination counts and height measurements were made August 4 and 5. Other apparent phytotoxic symptoms were also noted.

RESULTS

Treatments caused no noticeable delay of germination of the test grasses. Germination in both treated and untreated flats was

[1]Contributed by Manco Chemical Company, 500–506 Santa Fe Drive, Denver, Colorado.

[2]Contributed by Shell Chemical Corporation, Agricultural Chemicals Division, Denver, Colorado.

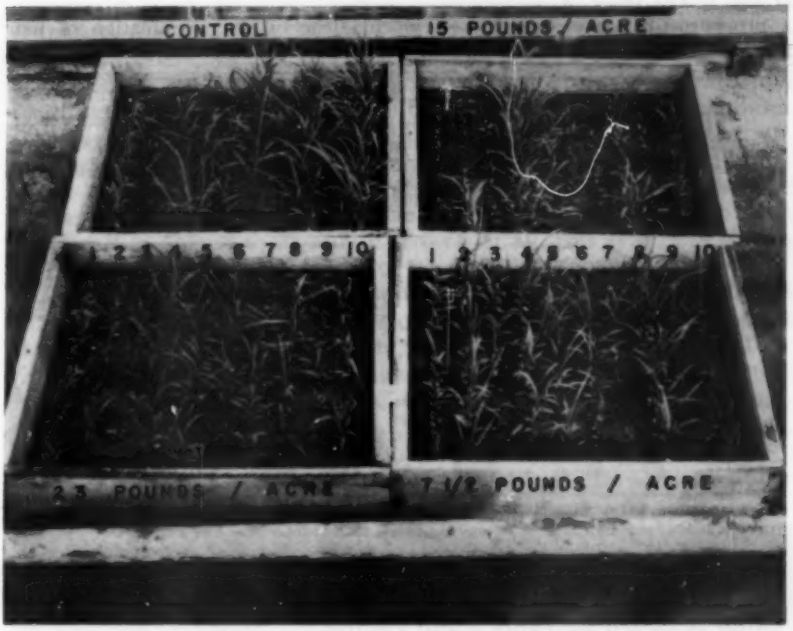


Figure 1. Chlordane (45 percent active ingredient) applied pre-emergence to crabgrass (rows 1, 3, 7, and 9 in each flat), sandbur (row 5), millet (rows 2, 4, 8, and 10), and green bristlegrass (row 6). Rates of application are 7½, 15, and 23 pounds per acre (equal to 1 pint per 2000 sq. ft.). Note the selective inhibition of crabgrass growth which decreases as rate of application decreases.

complete 5 to 6 days after planting. Only one treatment, CBP at 2 gallons of concentrate per 100 square yards, completely inhibited germination.

Stand counts three weeks after planting revealed that germination of all species, and especially that of crabgrass, was highly variable in both treated and untreated flats (Table 1). It was apparent that neither chlordane, CBP, nor hexachlorocyclopentadiene at rates up to 30 pounds per acre inhibited germination. All three chemicals at the 30 pounds per acre rate were observed to have higher germination of crabgrass than the control. (Results with the other three grasses were variable, as shown in Table 1.) All grasses failed to germinate with 2% CBP at the rate of 100 gal. per 100 square yards.

Following germination, several interesting results were observed. Chlordane (both types) at 15 and 30 pounds per acre inhibited growth of crabgrass, foxtail millet, and green bristle grass (Table 2). This inhibition was more pronounced against crabgrass than the other three species.

The 45 percent active chlordane formulation appeared to inhibit crabgrass growth to about the same degree as the 80 percent formu-

Table 1. The effect of pre-emergence applications of chlordane, chlorobromopropene (CBP), and hexachlorocyclopentadiene on the germination of four annual grasses.

Treatment	Rate lbs./A	Grass (seedlings per row ft.)			
		Crabgrass	Foxtail millet	Green bristlegrass	Sandbur
Chlordane (45%)	23†	107*	37	19	36
	30	100	24	15	37
	15	38	56	18	26
	7½	44	36	38	28
Chlordane (80%)	30	64	46	11	31
	15	18	24	23	33
	7½	81	43	23	31
CBP	30	60	55	27	31
	15	90	50	17	28
	7½	118	54	13	34
	2‡	0	0	0	0
Hexachlorocyclopentadiene	30	77	63	26	27
	15	89	37	56	26
	7½	78	68	43	29
Control		42	41	35	33

*Counts were made 3 weeks after planting. Each value given for crabgrass is the average of 4 determinations, for foxtail millet 4, green bristlegrass 1, and for sandbur 1 determination.
†Manufacturer's recommendation.
‡Gallons per 100 sq. yd.

lation as shown in Table 2 and Figures 2, 3, and 4. Thus formulation produces little or no effect when applications were made on the basis of active ingredients.

Table 2. The effect of pre-emergence applications of chlordane, chlorobromopropene (CBP), and hexachlorocyclopentadiene on the height of four annual grasses.

Treatment	Rate lb/A	Av. height in centimeters*			
		Crabgrass	Foxtail millet	Green bristlegrass	Sandbur
Chlordane (45%)	23†	5.7	10.3	10.9	11.9
	30	3.2	7.6	12.3	8.3
	15	4.2	13.5	11.0	13.7
	7½	5.7	13.5	10.6	11.3
Chlordane (80%)	30	2.2	8.8	11.1	10.4
	15	6.5	15.7	17.5	16.2
	7½	6.3	11.0	14.1	10.0
CBP	30	9.7	16.3	18.4	15.5
	15	9.2	15.1	18.9	14.8
	7½	11.6	16.8	14.2	14.5
	2‡	0	0	0	0
Hexachlorocyclopentadiene	30	12.6	19.9	16.1	18.4
	15	8.6	12.0	17.0	15.1
	7½	8.0	11.8	10.8	13.3
Control		10.4	19.4	21.6	13.4

*Measurements were made 3 weeks after planting. Each value for crabgrass is the average of 12 measurements, for foxtail millet 12, green bristlegrass 3, and for sandbur 3.
†Manufacturer's recommendation.
‡Gallons per 100 sq. yd.

It was evident that chlordane produced metabolic changes in the crabgrass plants. Interference with phloem function in translocation, is indicated by the fact that anthocyanin pigments (red color) appeared in the leaves of the most strongly suppressed crabgrass seedlings soon after germination. This red color persisted for about three weeks, then the affected seedlings turned brown and died.

Pre-emergence treatments with CBP and hexachlorocyclopentadiene produced no marked effects upon the growth of the four grasses at 7½ and 15 pounds per acre. At 30 pounds per acre both chemicals appeared to stimulate growth of all four grasses as shown in Figure 2.

These tests have confirmed the work of Pinckard (10) who found that CBP can be used as a soil sterilant. When it became apparent that CBP at 2 gallons of concentrate per 100 square yards had inhibited all grass seed germination, persistence tests were conducted. Kentucky bluegrass was planted on top of the original plantings, disturbing the surface soil as little as possible, at intervals of two, three, and four weeks after the date of treatment. Depth of planting was ¼ inch and two rows were planted at each date. At all three

Figure 2. Effects of 30 pounds per acre pre-emergence treatments of chlordane (45 percent and 80 percent), CBP, and hexachlorocyclopentadiene (P–162). Crabgrass in rows 1, 3, 7, and 9 in each flat; foxtail millet in rows 2, 4, 8, and 10, green bristlegrass in row 6; and sandbur in row 5. Note the selective inhibition of crabgrass by both treatments of chlordane and the stimulation of all grasses by CBP and hexachlorocyclopentadiene. Comparisons made on an active ingredient basis.

FIGURE 3

EFFECTS OF PRE-EMERGENCE CHLORDANE, CBP, AND P-162 TREATMENTS ON HEIGHT OF FOUR GRASSES

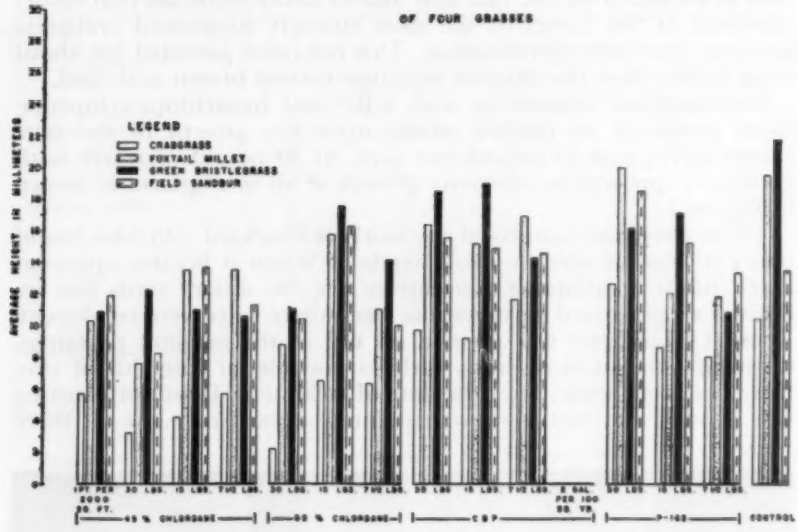
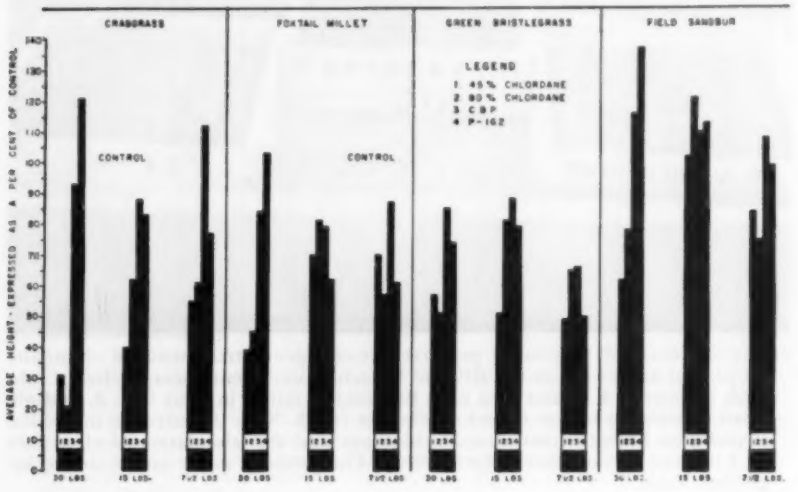


FIGURE 4

EFFECTS OF PRE-EMERGENCE CHLORDANE, CBP, AND P-162 TREATMENTS ON HEIGHT OF FOUR GRASSES



planting dates the bluegrass exhibited high germination within a week and produced subsequent normal growth. This indicates either, that CBP does not affect blue grass germination or that CBP disappears relatively rapidly from the soil. From this test, as shown in Figures 5 and 6, it appears that CBP may be used to kill weed seed in soils being prepared for new lawns. Extensive field tests will be necessary before specific recommendations can be made.

DISCUSSION

In 1951, Grigsby (5) reported that chlordane at rates of 5 to 25 pounds per acre delayed and prevented germination of crabgrass seed. He also found that, when applied to lawns in an oil spray such as kerosene, chlordane would kill crabgrass at any stage of growth with only mild effects upon the other turf grasses. The tests reported in the present investigation indicated that chlordane does not inhibit and may even stimulate crabgrass germination when applied pre-emergence *in water* at rates as high as 30 pounds per acre. However, the chlordane treatments do selectively inhibit the subsequent growth of crabgrass seedlings, which, from the point of view of control, may be just as effective.

In his tests with chlordane, Grigsby (5) planted crabgrass seed in flats on the soil surface, watered by flooding, and applied treatments

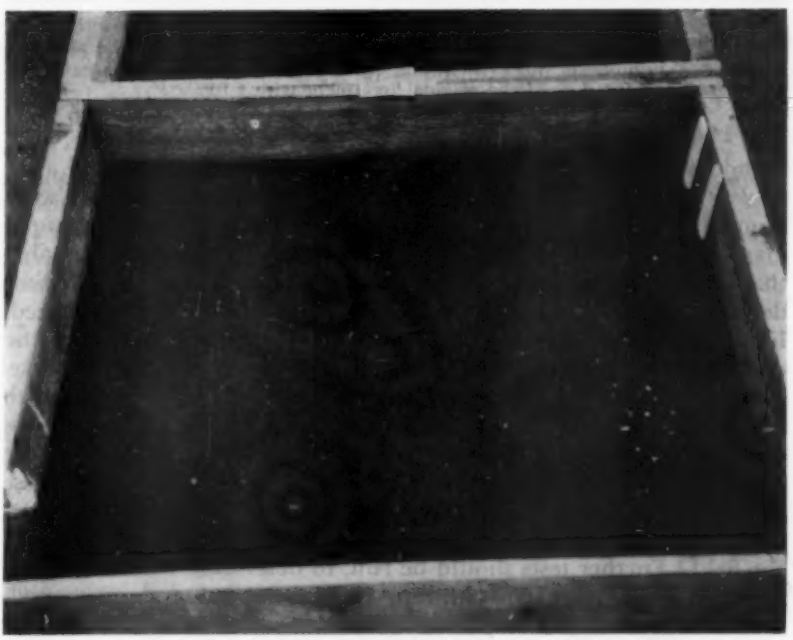


Figure 5. Germination inhibition effect of chlorobromopropene (CBP) at a rate of 2 gallons per 100 square yards, 2 weeks after treatment. Compare with control in Figure 2.

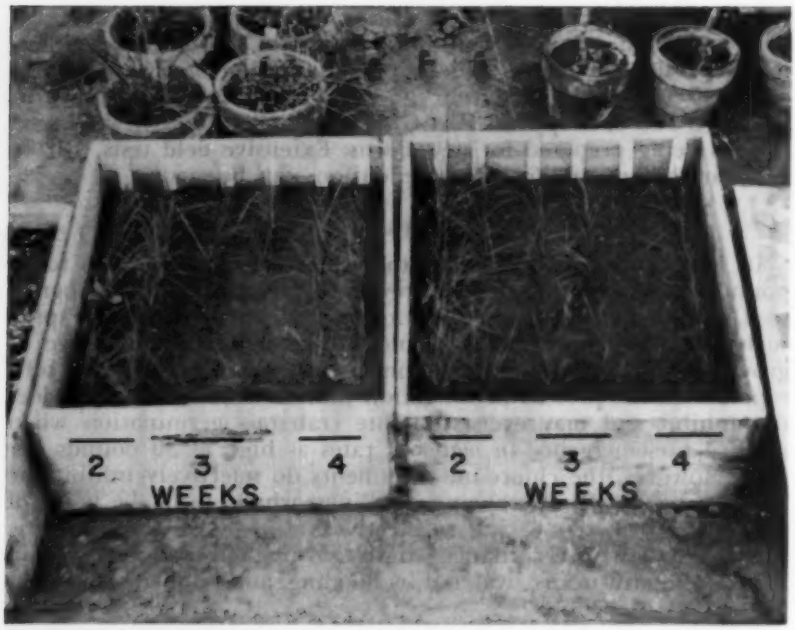


Figure 6. Kentucky bluegrass (*Poa pratensis* L.) planted after soil sterilization with CBP at 2 gallons per 100 square yards. Rows are marked on the photo to show the number of weeks elapsing between the date of planting of the bluegrass and the date of the original treatment with CBP.

24 hours later. In the present study, treatments were applied after seeds were planted and covered with ¼ inch of soil. All flats were immediately watered after treatment. These differences in technique may explain the differences in affects on germination. It is probable that chlordane applied pre-emergence to seed on the soil surface will delay and prevent germination and also will inhibit growth of seedlings originating from seed below the surface. If this is true, then the differences between the results of Grigsby's tests (5) and those reported here may be explained. It appears that chlordane applied to lawns in early spring might prevent germination of some crabgrass seed and might inhibit the growth of surviving seedlings to the extent that other lawn grasses can crowd them out of the turf. These results may be obtained from applications of 15 to 30 pounds per acre under greenhouse conditions. Higher rates may be necessary in the field.[1] Further tests should be run, to determine whether higher rates of application will inhibit germination of crabgrass, seeds below the soil surface.

[1]Recent correspondence with W. C. Shaw indicate 90 pounds per acre may be necessary for adequate control for a single pre-emergence application.

Tests are now being conducted at this Station to determine the effectiveness of chlordane in oil compared to chlordane in water when applied to lawns at various seasons of the year. The results of these tests will be available in the fall of 1954.

The present study has shown that CBP and hexachlorocyclopentadiene are ineffective as pre-emergence crabgrass herbicides at rates of 7½ to 30 pounds per acre. The growth stimulation observed with both chemicals at 30 pounds may have been due to their fungicidal effects, as CBP and hexachlorocyclopentadiene are known to have fungicidal properties. The growth stimulation observed may have been due to the reduction of pathogenic soil organisms in the unsterilized soil.

This study has also revealed one other interesting fact. Hexachlorocyclopentadiene is known to be one of the main impurities in technical chlordane (7). Since this material had little herbicidal effect upon the four annual grasses tested, the herbicidal effects of technical chlordane are evidently not due to the hexachlorocyclopentadiene impurity.[1]

[1]Chlordane *as now* manufactured (July 1, 1954) by Velsicol Corporation, Chicago, Illinois is reported to be free of hexachlorocyclopentadiene.

SUMMARY

It was found that the growth of crabgrass seedlings was selectively inhibited by pre-emergence applications of technical chlordane in water emulsion at rates of 7½ to 30 pounds per acre. At the same rates germination of crabgrass seed was not inhibited.

Chlorobromopropene and hexachlorocyclopentadiene had no pre-emergence herbicidal effects upon crabgrass at rates of 7½ to 30 pounds per acre but did stimulate seedling growth. Chlorobromopropene, when applied at the rate of 2 gallons per 100 square yards, was shown to be a powerful soil sterilant with residual effects that lasted no longer than two weeks under the conditions of the experiment.

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Dalapon (2,2–Dichloropropionic Acid) As a Protein Precipitant

CARL T. REDEMANN and JOHN HAMAKER, *Western Division Agricultural Research Laboratory of The Dow Chemical Company, Seal Beach, California*

SHORTLY after we had completed several studies of the effect of the new herbicide, dalapon, (2,2–dichloropropionic acid), on enzyme systems, it became apparent that high concentrations of this compound inhibited a variety of different enzymes in a non-competitive fashion. Furthermore, transparent solutions of enzymes frequently became quite turbid when this inhibitor was added. Such behavior suggested that 2,2–dichloropropionic acid was acting as a protein precipitant.

In order to obtain an estimate of the ability of 2,2–dichloropropionic acid to precipitate protein, a 2.5 percent solution of dried egg albumin was prepared in distilled water and filtered. To 5 ml. aliquots of this stock solution, contained in Kolmer graduated centrifuge tubes, were added varying quantities of diluted 2,2–dichloropropionic acid. After standing 20 minutes, the resulting suspensions were centrifuged at 2500 r.p.m. for 10 minutes. The volume of sediment was taken as a measure of the protein precipitated. The data in Table 1 show that such a precipitation becomes noticeable at concentrations of 2,2–dichloropropionic acid in the order of 200 ppm.

Table 1. Quantities of egg albumin precipitated by 2,2–dichloropropionic acid.

Concentration of 2,2-dichloropropionic acid	Volume of precipitate from 5 ml. of 2½% egg albumin
23,300 ppm	1.5 ml.
12,700	0.40
6,680	0.10
2,300	0.06
1,270	0.06
668	0.004
230	0.001
127	none
67	none

A second experiment was devised to show a comparison between the effectiveness of 2,2–dichloropropionic acid and trichloroacetic acid as protein precipitants.

Samples of fresh egg albumin and egg yolk were diluted with equal weights of water and analyzed for nitrogen content by the Kjeldahl method. Subsequently, 1 gram of trichloroacetic acid was added to 19 grams of each protein source, as was also 1 gram of 2,2–dichloropropionic acid. After standing 30 minutes, the samples to which the acids had been added were centrifuged, and the

clarified supernatant was analyzed for Kjeldahl nitrogen. The results presented in Table 2 indicate that, like trichloroacetic acid, 2,2–dichloropropionic acid is an effective protein precipitant.

Table 2. Kjeldahl nitrogen analyses of several fractions from egg yolk and egg albumin.

	Egg yolk	Egg albumin
Native, diluted 1:1	0.98% N	1.09% N
Supernatant from 2,2-dichloropropionic acid treatment	0.081%	0.064%
Supernatant from trichloroacetic acid treatment	0.052%	0.058%

This observation should serve as a word of caution to any other workers seeking an interpretation of the unique herbicidal action of 2,2–dichloropropionic acid.

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for April, May, and June 1954

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Prepared By

Division of Weed Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Section of Weed Investigations does not assume responsibility for the subject matter cited.

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